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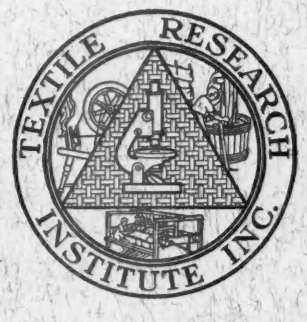

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TEXTILE RESEARCH JOURNAL

VOL. XVII, No. 6 June, 1947

Notes on the Resilience of Pile Floor Coverings

O. P. Beckwith* and J. L. Barach†

The following papers by members of the staff of the Product Engineering and Research Laboratories of the Alexander Smith & Sons Carpet Company are based on a discussion of Resilience of Pile Floor Coverings presented in a Symposium on Resilience of Fibers and Fabrics sponsored by The Institute of Polymer Research at The Polytechnic Institute of Brooklyn, January 25, 1947. The papers cover a time period from 1932 to the present.

Part I—1932-1942

Quality Control

The first attempts to apply scientific methods in improving carpet manufacturing techniques took place in the early 1930's. These efforts were aimed primarily at controlling and improving quality. Those engaged in the work were, in general, engineers by training and consequently their approach to the problems was an engineering one.

The paramount quality problem in pile-floor-covering manufacture lies in control of the principal and costliest raw material—wool. All carpet wools are imported into the United States. They are raised on every continent except North America. There are over 200 different commercial types. Carpet wools can be classified into two groups according to origin —those from crossbred sheep and those from native sheep. The former are found in the British Isles, South America, Australia, and New Zealand; the latter come from many countries, notably India, Egypt, Iceland, Tibet, China, the Near East, and the Mediterranean basin.

Different carpet-wool types vary in their physical and chemical characteristics. They differ in dyeing, spinning, and product properties. Judicious selection of wools for blends is probably the most important single factor in achieving efficient processing and good product quality. The engineer, in tackling the problem of selection of wools for blends, accepted the practical man's knowledge of carpet-wool quality. He carried it to its logical conclusion: classification and measurement of the properties of various wool types.

Need for Resilience Measurement

The need for measurement of the properties of wools which are related to their performance in use stimulated the development of test methods. Fineness, length, strength, spinnability, wear, coverage, shedding, and other tests were devised and successfully used. One outstanding quality characteristic eluded measurement; this was the property which would predict how a wool surface would withstand the effects of traffic. Some wools when walked on

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Mr. Beckwith wrote Part I of this report, and Mr. Barach wrote Part II.

TABLE I. FORM FACTORS OF SAMPLES

Sample No.	Density (g./cu. in.)	Pile height (in.)
1	24.8	0.19
2	28.6	0.19
3	31.8	0.19
4	37.1	0.19
5	40.4	0.19
6	32.1	0.13
7	30.6	0.16
3	31.8	0.19
8	31.9	0.25
9	31.8	0.29
10	32.6	0.38

TABLE II. PERCENT RESILIENCE OF SAMPLES

Sample No.	Pile height (in.)	Density (g./cu. in.)	Resilience (%)
1	0.19	24.8	22.1
2	0.19	28.6	22.5
3	0.19	31.8	21.3
4	0.19	37.1	21.0
5	0.19	40.4	21.1
6	0.13	32.1	24.3
7	0.16	30.6	28.4
3	0.19	31.8	21.3
8	0.25	31.9	22.4
9	0.29	31.8	27.2
10	0.38	32.6	21.0

in carpet form flatten down readily and portions of the pile lie in different directions, causing unattractive light-reflection patterns. The fabric surface takes on a "mangy," "scraggly" appearance. Other wools do not crush as much; their surfaces are uniform and pleasing in appearance, with the pile lying in one direction.

Subsequently the rapid development of synthetic fibers caused the engineer to include them in his studies and evaluate them in the same manner as he did the wool types. Interest in these fibers was twofold: (1) the obvious economic advantages and (2) a source of pile fiber in the event that war started in Europe and interrupted the flow of wools.

For want of more knowledge the engineer considered that the ability of carpet-pile fibers to resist the distorting effects of traffic could be evaluated by measuring their resilience. Resilience was considered to be the ratio of the work returned upon release of a compressional load to the total work done in compression.

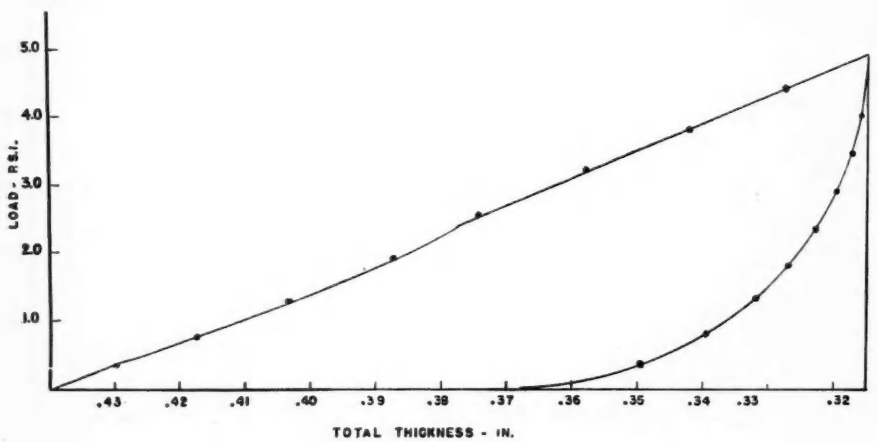

FIG. 1. *Load vs. compression curve—pile floor covering.*

The first attempts at the Alexander Smith & Sons Carpet Company to measure the resilience of carpet wools consisted of the application of a testing technique described in the *Journal of the Textile Institute* [1]. This consisted of measuring the change in volume of a mass of wool under pressures made to vary in a cyclical manner. The wool was enclosed in a thin spherical rubber membrane and the pressure of the surrounding atmosphere was varied. The area under the pressure-volume curve for increasing and decreasing pressures was determined and the percent resilience computed. The test method was not successful in that the value obtained, percent resilience, did not correlate with performance of the wools in service as a pile floor covering.

The Compressometer

At this time the compressometer developed by Dr. H. F. Schiefer [2] became commercially available. It was decided to use this instrument to determine resilience—not of fiber in bulk form, but of fiber in the form of pile floor covering. The compressometer provided a means for measuring thickness and the change in thickness of a textile when it was subjected to increasing or decreasing pressures.

The discussion which follows describes the work done with the compressometer up to 1942. No other instrument was used. The initial test technique consisted of loading the fabric to 5 pounds

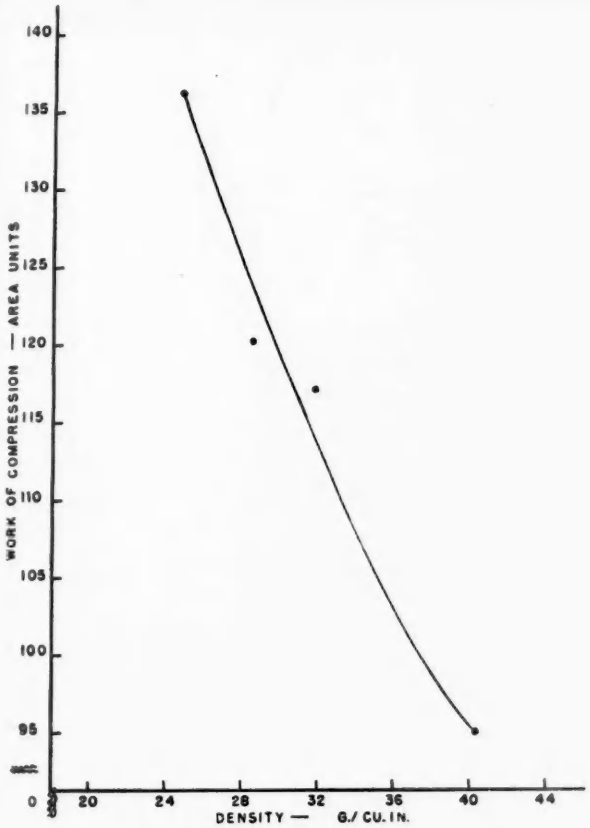

FIG. 2. *Density* vs. *work of compression.*

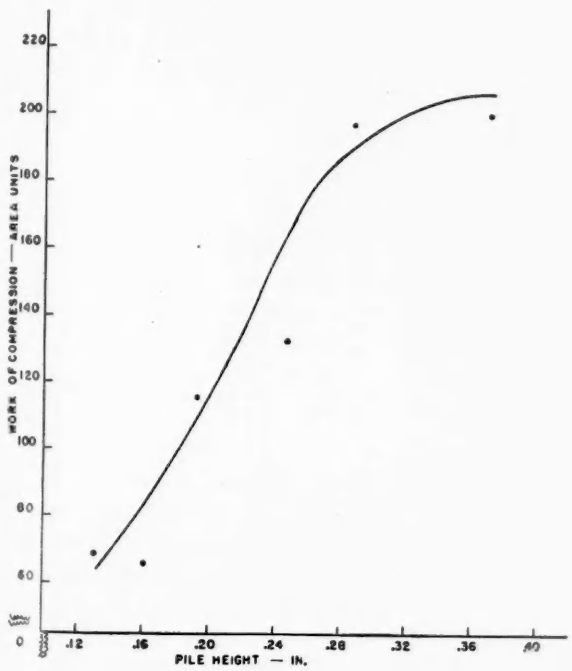

FIG. 3. *Pile height* vs. *work of compression.*

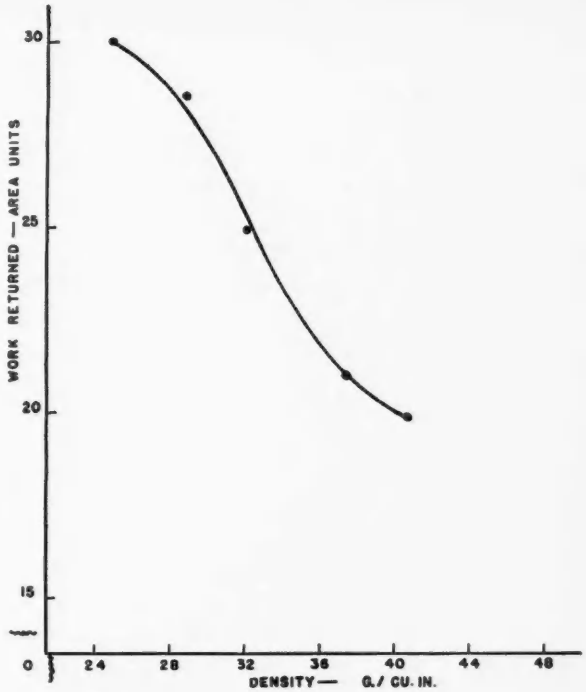

FIG. 4. *Density* vs. *work returned.*

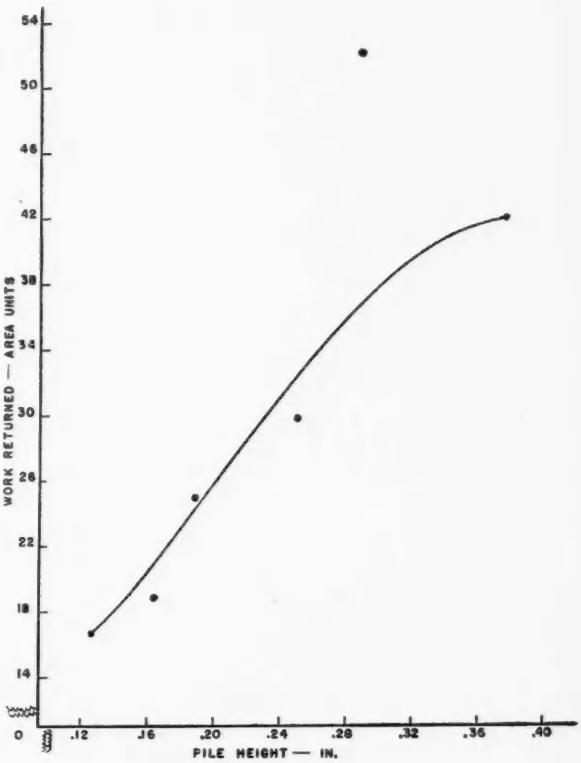

FIG. 5. *Pile height* vs. *work returned.*

per square inch in steps of 0.5 pound per square inch and unloading the fabric by the same amount. Load application was manual and when the desired pressure was reached the load was held briefly to record the thickness to the nearest 0.001 inch and then loading was resumed. A typical load-deflection curve is shown in Figure 1. After plotting, the areas under the curves were measured with a planimeter and the resilience was expressed as the ratio of the work returned upon release of load to the work done in compression.

In order to evaluate this technique of measurement a series of fabrics from one lot of yarn was made. These samples contained systematic alterations in the form factors of pile height and pile density. The characteristics of these samples are listed in Table I. Samples 1–5 are constant in pile height, but differ in density. Samples 6–10 are constant in density, but differ in pile height.

The percent resilience of the samples described in Table I was determined by the method previously discussed. The values of percent resilience are given in Table II. It is apparent from these data that percent resilience as determined by this test method does not enable any differentiation among the fabrics as to the response of each to the same forces. In floor service these carpets would perform differently; it would be expected that some would crush more than others, depending upon the density and pile height of each. The feeling of "luxury" in walking on each would be different. The "shading" or "laying" of the pile would be different, depending on the sample. Therefore, the values of resilience as determined in this test had no meaning in terms of service performance of the samples.

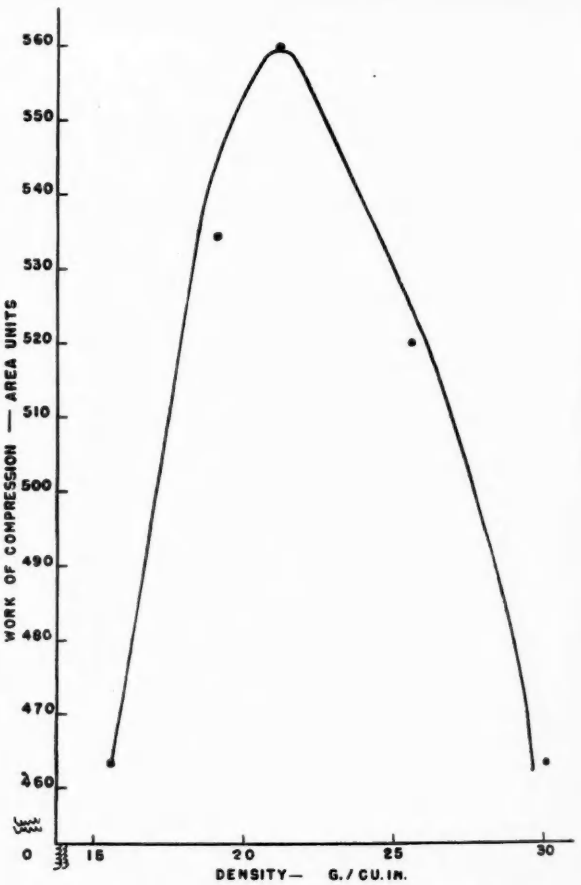

FIG. 6. *Density vs. work of compression.*

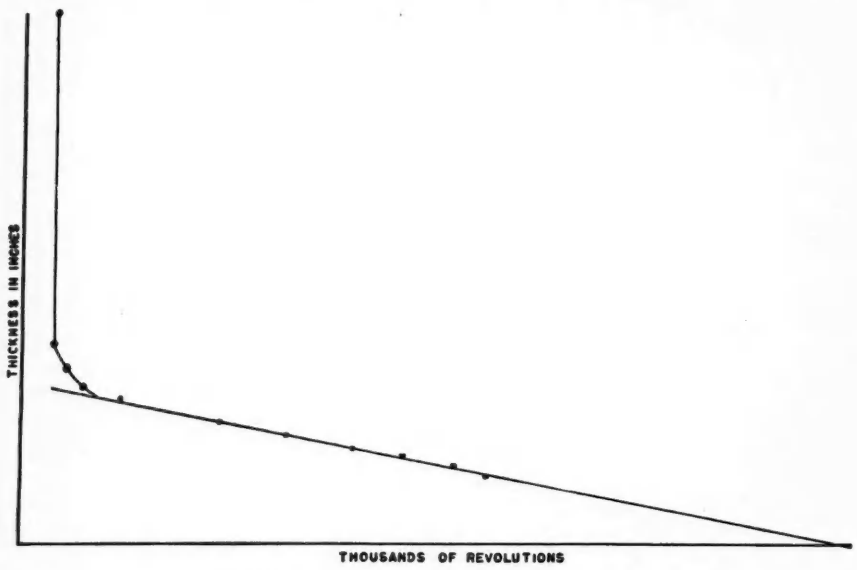

FIG. 7. *Wear test curve—velvet carpet.*

The data composing the ratio, percent resilience—that is, work of compression and work returned—were studied. Figures 2, 3, 4, and 5 are graphs of work of compression vs. density and pile height and work returned vs. density and pile height, respectively.

Figure 2 (density vs. work of compression) shows a curvilinear relationship between density and work, pile height being constant. Subsequent studies showed that as density increases from a low value the

TABLE III. WORK OF COMPRESSION—VARIOUS VISCOSE RAYONS AND WOOL

Sample	Work done (area units)
No crimp—viscose rayon	433
25% crimp—viscose rayon	325
50% crimp—viscose rayon	321
75% crimp—viscose rayon	305
100% wool	300

work done reaches a maximum and declines (see Figure 6). Such a relationship appears reasonable. It is expected that at low densities the effect of the force would be to collapse the pile quickly, the relatively immovable backing structure absorbing most of the applied force. As density increases, more of the force is dissipated by the resistance of the pile to bending. Finally, as the density of the pile further increases, the resistance to bending becomes so great that the work done declines.

Figure 3 (pile height vs. work of compression) shows that as pile height increases with constant density work done increases but reaches a maximum and levels off. This is a logical relationship. With low pile height the pile is quickly collapsed and the force is dissipated against the back structure. As pile height increases more and more of the force is absorbed by the pile and less by the back until finally the pile bending completely absorbs the force. Beyond this point no further changes in work done would be expected.

Figure 4 (density vs. work returned), pile height being constant, shows, for the range covered, that as density increases work returned decreases. This is to be expected since the greater the density the more fibers there are. Therefore, when the force deforms the pile at high densities more fiber entangling takes place, thereby reducing the ability of the fibers to return. No data are available as to the extent of work returned on piles of lower density than those covered in Figure 5.

Figure 5 (pile height vs. work returned), density being constant, shows, for the range covered, that work returned increases as pile height increases, reaches a maximum, and levels off. Since the effect of the back structure is gradually eliminated with increased pile height, this relationship is to be expected.

The foregoing data indicated two general conclusions: (1) the effect of a force on the pile of a floor covering is better expressed in terms of the work done and work recovered than by the ratio of these two values; (2) form factor plays an important part in the "resilient" or "elastic" characteristics of the pile floor covering.

The results obtained in the trials discussed above stimulated thinking as to the characteristic in service use which the laboratory test should evaluate. It was felt that the sensation desired by the user in walking on a pile floor covering was one of luxury—that is, the pile should bend and give gradually under the impact of the foot, and the greater the give the more luxurious and desirable the fabric. It was felt that the amount of work immediately returned would not be so effective a criterion. The ability of the pile eventually to return to its original height after compression was deemed important but this was not investigated at the time. It was concluded that an important service characteristic directly related to what the user wants in a pile floor covering is the amount of work done in compressing the pile with a given force.

The value, work of compression, was determined for several experimental samples. These samples were woven in the same construction but each contained fiber variations. The results are given in Table III. These data show a series of 100-percent viscose rayon samples to be superior to wool in terms of work of compression and therefore more "resilient" than wool. However, in service the reverse was true. The rayon crushed more and had a less desirable surface appearance than wool. Therefore, work of compression did not, in practice, indicate what would occur in service.

These data made it apparent that the test method was unrealistic. For 90 percent or more of the service life of the floor covering the pile is compressed. In the test method described the pile of the sample being tested was always erect—that is, in the unused state—whereas during its service life it is never erect, but compressed or laid over. This condition is shown in Figure 7, a typical wear-test curve from the Bureau of Standards Type carpet wear test [3]. Pile thickness is plotted against revolutions. During the first few thousand revolutions the pile compresses from its original height to a new level. After compression of the pile, wear of the pile fibers proceeds at a linear rate until zero thickness is reached. (The form of the machine wear-test curve duplicates that obtained in floor service.)

It was then agreed that the determination of work done on a fabric should be made after its pile had been

TABLE IV. BEFORE COMPRESSING PILE: DENSITY VS. PERCENT RESILIENCE AND WORK OF COMPRESSION

Sample No.	Initial density (g./cu. in.)	Resilience (%)	Work done (area units)
18	35.1	19.7	122
19	37.1	16.9	148
20	37.9	19.5	141
21	46.8	21.2	80
22	52.4	22.9	53
23	53.4	17.9	52

TABLE V. AFTER COMPRESSING PILE: DENSITY VS. PERCENT RESILIENCE AND WORK OF COMPRESSION

Sample No.	Pile crushing (%)	Final density (g./cu. in.)	Resilience (%)	Work done (area units)
18	38.8	48.6	31.5	65
19	37.5	51.0	33.3	72
20	37.7	51.9	31.3	66
21	35.6	63.5	31.2	69
22	31.9	69.0	27.0	69
23	28.4	68.5	25.7	70

compressed as it is in the first stages of the machine wear test (and service use). Accordingly, a series of samples from the same lot of yarn were woven. The density was varied from sample to sample but pile height was kept constant. These were tested by the technique previously described—that is, the new fabrics were loaded by means of the compressometer to 5 pounds per square inch and the load was released. The work done was computed and the percent resilience was determined; these data are given in Table IV.

After the tests described in Table IV were done all samples were run on the Bureau of Standards machine to the point where the pile was compressed. All were run the same number of revolutions. Immediately after pile compression the work of compression in loading the pile to 5 pounds per square inch by a compressometer was determined. Data are given in Table V.

Comparison of Tables IV and V shows that in the compressed state percent resilience increased almost 100 percent from the uncompressed state. The work done on the piles of the samples after they had been run on the wear-test machines is practically the same for all samples, in contrast to very definite differences in the uncompressed state.

It was felt that the apparent equality of work done recorded in Table V was due to the interaction of the effects of pile height and density. It will be noted from the column headed "Pile crushing" in Table V that the amount which the pile flattened or crushed on the wear-test machines was roughly inversely proportional to the original density, the sample having the lowest density crushing most, the sample having the highest density crushing least. Therefore, while each had the same pile height initially, after compression they were of different pile thicknesses depending on their initial density. Density, of course, increased with crushing of the pile and although the same relationship existed as in the original samples, the spread between highest and lowest density was not so great.

From the relationship of density and work of compression discussed previously (see Figure 2) it would be expected that in Table V, sample No. 18 would have the greatest amount of work done and sample No. 23 the least. However, sample No. 18 (after compression) has the lowest pile thickness and sample No. 23 the highest. According to Figure 3 we would, therefore, expect that the work done in Table V should be least for sample No. 18 and most for sample No. 23. The two opposing conditions, it is believed, interacted to give in Table V essentially the same values of work done for all samples despite the original density difference.

It was concluded from the data of Table V that within a given range the form of a pile floor cover-

TABLE VI. WORK OF COMPRESSION ON COMPRESSED PILE OF EXPERIMENTAL SAMPLES

100% wool control	130
50% wool—50% viscose rayon	93
100% viscose rayon	68
100% wool control	122
No crimp—viscose rayon	53
25% crimp—viscose rayon	65
50% crimp—viscose rayon	60
75% crimp—viscose rayon	68
100% wool control	128
Resin treatment No. 1 (viscose)	89
Resin treatment No. 2 (viscose)	92
Resin treatment No. 3 (viscose)	79
Untreated (viscose)	60
100% wool control	138
Crimped acetate	110
Uncrimped acetate	95
100% wool control	130
Hollow acetate	92
Dumbell cross-section acetate	59

ing ceases to be a dominant factor in affecting work done by a given force if that force is applied after the pile has been compressed. Therefore, it was reasoned that if a series of fabrics of the same form but of different fiber content were tested in this manner, any significant differences that resulted must be due to the characteristics of the fiber alone and not to a combination of fiber characteristics and form. Accordingly a number of tests were run on different experimental fabrics (all in the same form factor). The data are given in Table VI. These data ranked the various fabrics in accordance with the order of their desirability in floor service—that is, in amount of crushing, surface appearance, and luxuriousness.

It is interesting to note the results on the second group of samples in Table VI. Data on these samples in the uncompressed pile state are given in Table III. The relationship of wool and viscose rayon is reversed in Table VI.

In all of the subsequent experimental work at Alexander Smith & Sons on the use of synthetic fibers in pile floor coverings the technique described above was used. It played a part in the development of a company policy governing the use of synthetic fibers in pile floor coverings. The fact that the rest of the carpet industry in this country ultimately adopted this policy is a partial measure of the effectiveness of the testing technique.

Part II—1946 to Present

The primary purpose of a carpet is to provide a covering for the floor which is at one time appealing to the eye and luxurious to the feel. The decorative characteristics are not our concern at this time and our attention is directed toward an empirical approach to the measurement of one of the most important of the luxury factors—namely, resilience. This term may be variously defined, but the definition which most closely fits our need is that which Dr. Harold deWitt Smith gave in the 1944 Edgar Marburg Lecture when he defined resilience as "the ability to absorb work without suffering permanent deformation." It is in that sense that the term is used in this paper.

The way in which carpet fabric is now made is the result of much thought and experimentation directed toward maximum resilience (and other desirable properties) with the most efficient use of the materials. Unfortunately, the resulting structure is complicated and does not lend itself well to theoretical analysis; however, certain simplifying assumptions can be made which will help. It can be assumed that the woven backing is a large solid and that the individual fibers are small cantilevers equally spaced on this back. It can be further assumed that these fibers are all alike and have the same physical properties. If the fibers were elastic and did not interact with each other, it would be easy to calculate the resilience characteristics of the resultant fabric. But a carpet does not lend itself to such measurement. The wool fibers in the pile not only rub on each other, making surface friction a very important factor, but the fibers are crimped and they interlock. Nor are the fibers elastic in the sense that they follow Hooke's law —that much may be inferred from the studies on the tensile properties of fibers which have been made. A corresponding analysis of the compressional characteristics of wool would be a very valuable contribution for it might point the way in which to form a better pile fiber.

This complexity of construction is not confined to carpets only and it has been recognized by many persons. We prefer to attempt a breakdown of the problem into simpler terms and, by making a series of fabrics all with similar characteristics, except for one variable, determine the effect of that variable on the resultant. However, it was first realized that the knowledge of service conditions was woefully small and the work reported herein is a series of measurements of the loading conditions which occur in actual use. Since the conditions which were to be measured were relatively unknown, the apparatus described is definitely crude and is open to many criticisms.

Figure 8 shows a plywood platform (A) 2 by 3 feet, to which a piece of carpet was tacked. This was supported at the four corners by J-shaped brackets (B). These brackets were in turn fastened to a larger plywood base (C). At the end of the long arm of the bracket a wire strain gage (D) was mounted to measure the load being applied to the other end by the platform (A). The gages were all connected in a D.C.-excited bridge circuit in such a way that the gage outputs were added. The resulting signal was then fed into the vertical amplifier of

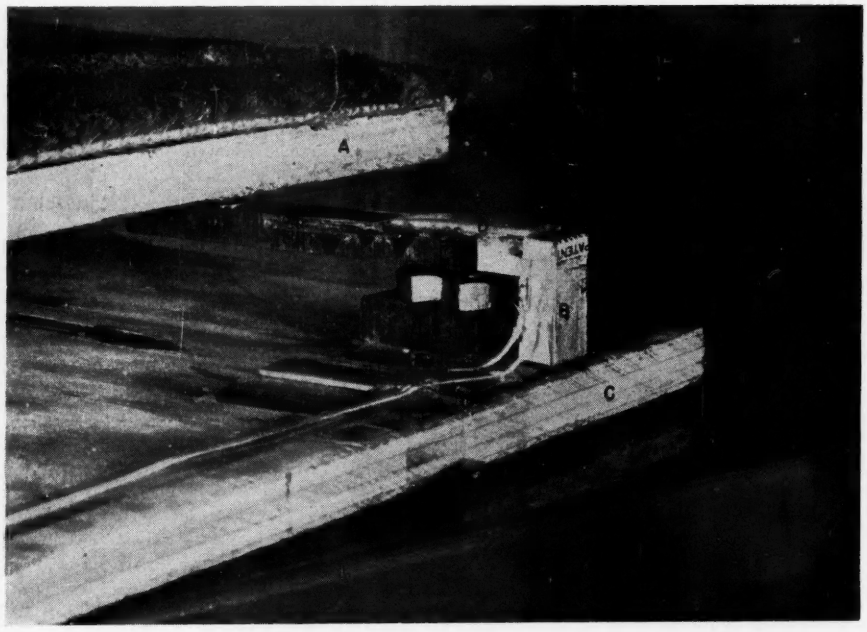

FIG. 8. *Supporting beam and platform of the load-measuring device.*

a cathode-ray oscilloscope. The signal which appears on the face of the cathode-ray tube represents the force being applied to the platform and is theoretically independent of the position at which the force is being applied.

Numerous laboratory personnel walked on our device and attempted to reproduce normal walking, as well as the climbing and descending of stairs. The range of weight and type of person varied from a man 6 feet 2 inches tall weighing 210 pounds, to a woman 5 feet 2 inches tall, weighing about 100 pounds. Two of the pertinent photographs are shown in Figures 9 and 10.

These photographs revealed several interesting things. Under a given type of walking, the rates of loading and unloading do not differ nearly so much as one might guess. These figures were averaged and Table VII shows the loading, duration, or transition and unloading times for the series of subjects.

Because of the simplicity of the apparatus, it was not possible to determine the unit loading conditions in terms of pounds per square inch, but the average peak load was estimated at 12 pounds per square inch walking and up and down stairs. The same apparatus was then used again only this time it was excited with 60-cycle voltage from a transformer attached to the lighting system. This A.C. excitation overcame one of the fundamental faults with the first study—that is, the inability of the system to respond to a steady load. Thus we have a means of determining directly the magnitude of the peak loads and also the shape of the curve during the transition period. The figures in Table VIII show the results which were obtained using this type of excitation applied to walking on a level floor.

Since the same subjects were used in both series of experiment, the variation was due to differences in manner of walking. Figures 11 and 12 are examples chosen from the series of measurements made with A.C. bridge excitation.

We know that an average person standing on a carpet on both feet loads a carpet 3 to 5 pounds per square inch. Standing on one foot would, of course, double this load when the full area of the foot is on the carpet. When a person walks, the area is reduced as soon as the heel is lifted. Thus, even this measurement is not too accurate. The A.C. bridge excitation makes it possible to check these peak loads and we find that, except when the subject is descending stairs, the total loads never go above the static load. During descent of stairs, the peak loads approach 1.25 times the static load. The unit loads, however, go considerably higher owing to the reduction of the area mentioned above—probably up to twice the static load. However, these values correspond roughly to the loadings previously employed in our tests with the compressometer when used to determine load-thickness characteristics. It is also interesting to note that Dr. Schiefer at the Bureau of Standards arrived at a value of 10 pounds per square inch on the carpet wear-test machine that he de-

TABLE VII

Type of step	Part of step	Time to complete step (sec.)
On level floor	Loading	0.16
	Transition	0.57
	Unloading	0.14
Climbing up and down stairs	Loading	0.085
	Transition	0.32
	Unloading	0.12

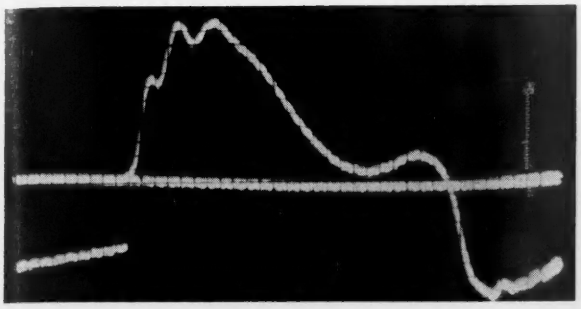

FIG. 9. *Step on level floor (D.C. excitation).*

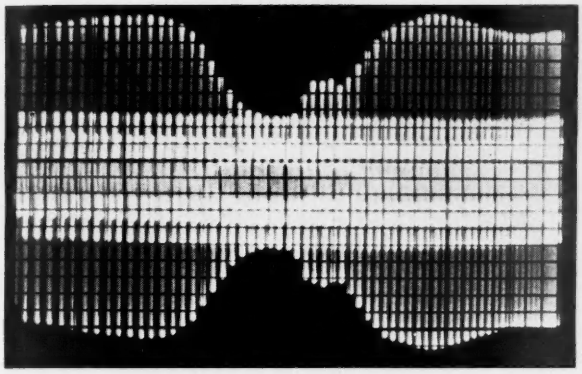

FIG. 11. *Step on level floor (A.C. excitation).*

signed and that is now used extensively in the industry.

It is a rather obvious step to apply these data in the selection of rates of loading to be used in single- or multiple-cycle compression tests (see Table VII). The carpet should be loaded at the rate of 120 pounds per second to a peak load of 12 pounds per square inch, the load maintained for ½ a second, and then be withdrawn at a rate of 120 pounds per second. If it is loaded for more than one cycle, then this same cycle should be repeated. With the compressometer it was loaded in 90 seconds and unloaded in about the same length of time. One of our problems will be to show whether or not the two types of loading are comparable. If they are not, then test equipment is needed to reinvestigate the findings made with the compressometer. As far as the writer knows, the only comparable testing apparatus designed to test under conditions closely approximating

TABLE VIII

Type of step	Part of step	Time to complete step (sec.)
On level floor	Loading	0.22
	Transition	0.50
	Unloading	0.18

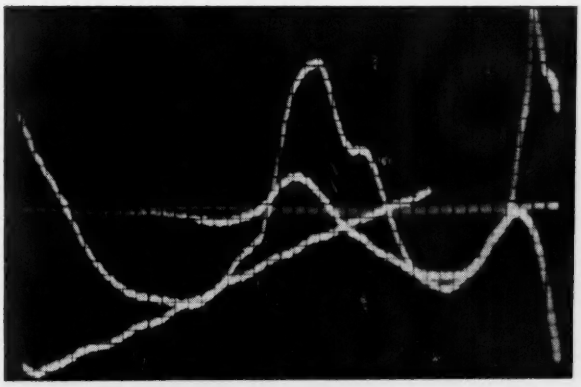

FIG. 10. *Descending steps (D.C. excitation).*

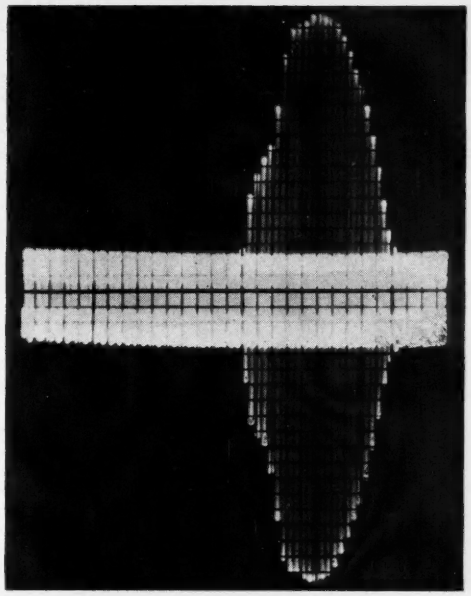

FIG. 12. *Running on level floor (A.C. excitation).*

use is the parachute shroud-line tester in the Slater Laboratory at the Massachusetts Institute of Technology.

How this can be translated into a meaningful measure remains to be seen. The end result to be hoped for is a further insight into the influence of fiber properties upon the properties of the product.

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1. Winson, C. G., Report on a Method for Measuring the Resilience of Wool, *J. Text. Inst.* **23**, T386–93 (1932).
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Endurance of Cotton Tire Cords and Fibers Under Static Tensioning

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THE cords in an automobile tire are subjected to three types of stressing: low, continuous static stressing by the normal inflation pressure; uniform intermittent dynamic stressing during the rolling of the wheel under load and traction over smooth surfaces; more or less drastic irregular dynamic stressing when carrying a load under traction over obstacles. Whereas the intermittent dynamic stresses may determine the span of satisfactory performance, static endurance tests give a broader view of performance as concerns strength. Tests based upon dynamic stressing must be employed in comparing tire cords and checking the effect of various processings and structures; but for proper interpretation of endurance under conditions of flexing, it appears that endurance under conditions of static tensioning must be known. Even in ordinary standard methods of determining the "tensile strength" or "breaking load" under certain fixed conditions, results can be more fully understood in the light of static tests.

The effect of flexing must be analyzed as something beyond a mere static property of static endurance under tension. Thus the time of endurance under static tensioning must be determined, as well as the nature of the failure—that is, whether breaking results from the movement of fiber past fiber or from the movement of the microscopic and submicroscopic structural elements, the chain bundles.

There are few data in the literature on endurance of tire cords under static tensioning, and particularly few concerning tire cords fabricated from American cotton [3]. This paper is a report of some findings which were incidental in a series of studies under way at the Southern Regional Research Laboratory on the utilization of American cotton in tire cords. The data given are not intended to be a basis for accurate comparative evaluation of the different tire cords mentioned. They are of a preliminary nature and indicate merely the importance of static endurance.

* Deceased March 27, 1946.

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Tire-Cord Measurements

Samples

The measurements of time of endurance of tire cords under static tensioning were made for the most part either on experimental cotton cords fabricated and mercerized at this Laboratory, or on those fabricated by a commercial manufacturer from cotton of a known variety. Three commercial cords, two rayon and one cotton, were also used.

Certain characteristics to identify these samples are given in Table I.

Fiber properties of cottons used in experimental cords are given in Table II.

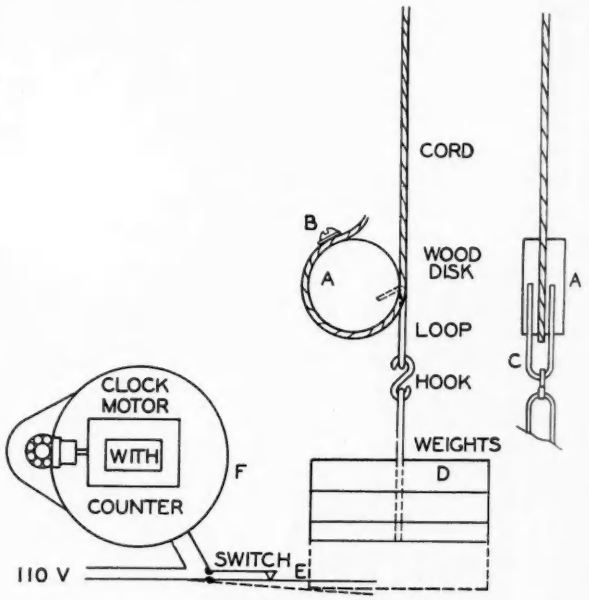

FIG. 1. *Means of anchoring cords for static tensioning tests.* A, *wood disk with the holding screw,* B, *and with hooked loop,* C, *for receiving weights,* D, *which, upon rupturing of the cord, fall upon lever of switch,* E, *to stop timer motor,* F.

TABLE I. IDENTIFYING CHARACTERISTICS OF THE TIRE CORDS USED

Cord description and number	Construction	Twist		Diameter (mils.)	Count	70°F, 65% R.H. Strength (lbs.)	70°F, 65% R.H. Elongation at 10 lbs. (%)	Oven dry 224°F Strength (lbs.)	Oven dry 224°F Elongation at 10 lbs. (%)
		Ply	Cord						
Commercial									
1. Rayon	1100/2	14.2	10.5	22.8	2.09	13.35	10.2	17.22	5.5
2. Rayon	1100/2	18.5	12.4	24.0	2.12	13.72	10.3	17.28	5.8
3. Cotton	23/4/3	19.6	10.3	27.4	1.73	14.18	4.4	13.08	5.7
Experimental* unmercerized									
4. Wilds 13†	17/4/3	20.3	9.9	30.4	1.19	25.46	4.8	24.35	4.2
5. Stoneville 2B	22.75/4/3	27.1	10.6	30.5	1.47	14.45	12.2	11.98	10.7
6. Acala 1517 treated‡	22.75/4/3	20.0	10.3	24.7	1.76	16.92	3.5	15.95	3.8
Experimental mercerized									
7. Wilds 13†	17.5/4/3	18.1	9.7	29.6	1.22	22.62	4.1	23.44	5.2
8. Stoneville 2B M-11-3**	22/4/3	20.6	9.6	25.0	1.73	16.35	8.6	18.3	4.8

* 1943 crop.
† Prepared on a commercial basis.
‡ Wet twist and stretched.
** Stretched.

Method

A cord of sufficient length to give a 10-inch test specimen was attached at one end to a rigid beam by means of a special clamp. At the other end, a similar clamp was used to attach a freely hanging weight, *D*, as illustrated in Figure 1. The short cylinder, *A*, of hard wood about 7/8 inch in diameter, 3/8 inch thick, was attached to the weight with a loop, *C*, of heavy wire. The specimen, anchored by tying (or by a loop) to a screw, *B*, was passed around the cylinder through the wire loop, *C*. A weight of 4 ounces was placed in each cord, giving sufficient tension to maintain a loaded position until the weight was applied. The cord was tensioned from a moving platform with a vertical speed, in accordance with A.S.T.M. specifications for determining tensile strength [1], of 12 inches per minute. When the cord was supporting the weight, the micro-switch, *E*, placed beneath the weight, closed the timer circuit. Time of endurance was totalized on a motor-driven counter reading to

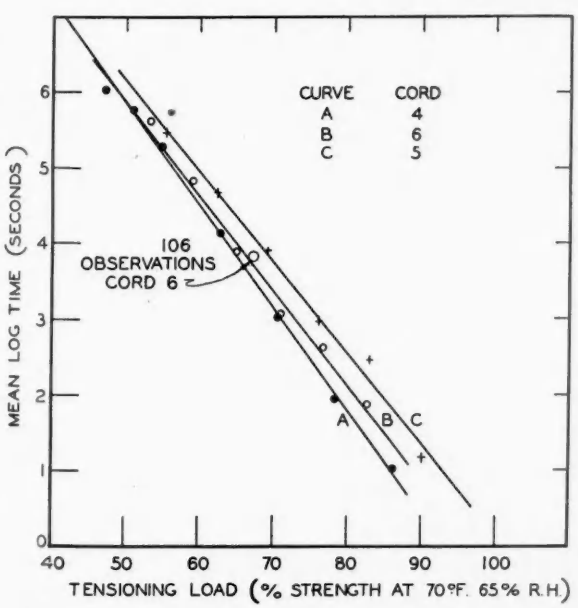

FIG. 2. *Logarithm of time under static tensioning vs. load of tensioning for experimental cotton cords 4, 5, and 6.*

TABLE II. FIBER PROPERTIES OF COTTONS USED IN EXPERIMENTAL CORDS

Variety	Wilds 13	Stoneville 2B	Acala 1517
Year produced	1943	1943	1943
Grade	SM	SM	SM
Staple length	$1\frac{3}{8}$ in.	$1\frac{1}{8}$ in.	$1\frac{5}{32}$ in.
Fiber length			
(*a*) 25% point	1.452 in.	1.252 in.	1.331 in.
(*b*) Mean	1.142 in.	1.058 in.	1.121 in.
(*c*) Coefficient of variation	36.6%	26.9%	27.7%
Tensile strength*	94,800 p.s.i.	80,000 p.s.i.	81,400 p.s.i.
Weight fineness	3.32 μg./in.	4.17 μg./in.	4.18 μg./in.

* Estimated Chandler strength from Pressley Index.

TABLE III. TYPICAL OBSERVATIONS FOR COTTON CORD 4 (TABLE I), UNDER ROOM CONDITIONS

Load		Time before break			
Pounds	Percent*	Days	Hours	Minutes	Seconds
13	51.0	6	16	35	—
14	54.9	2	4	43	—
16	62.7	—	3	32	50
18	70.6	—	—	17	37
20	78.4	—	—	1	27
22	86.3	—	—	—	10

* Percentage of tensile strength.

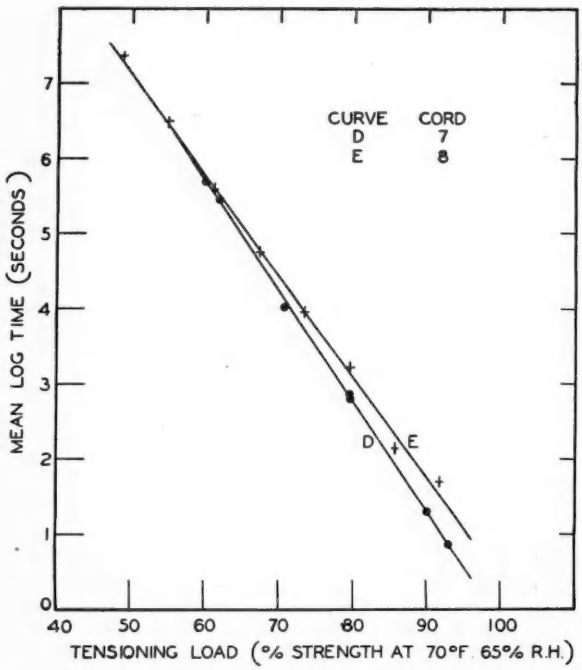

FIG. 3. *Logarithm of time under static tensioning vs. load of tensioning for experimental mercerized cotton cords 7 and 8.*

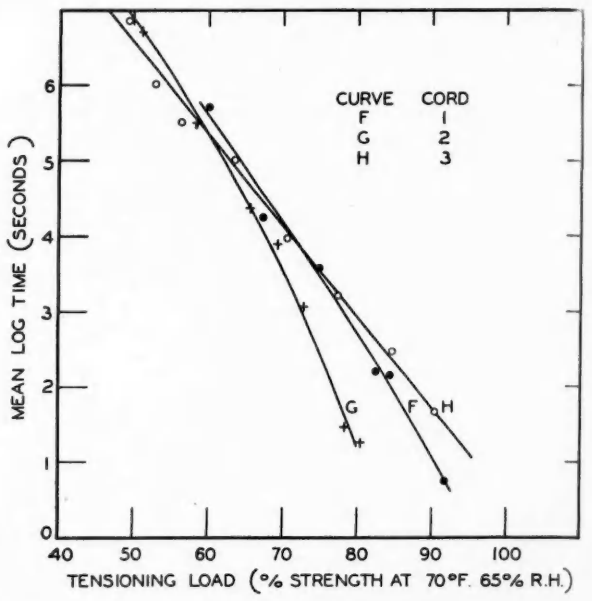

FIG. 4. *Logarithm of time under static tensioning vs. load of tensioning for commercial rayon tire cords 1 and 2, and commercial cotton tire cord 3.*

0.1 second and recorded in seconds for high tensionings. In the recorded results, tensioning load is expressed as a percentage of the cord strength, the latter being determined, in most cases, at 70° F, 65 percent relative humidity, with a pendulum-type tire-cord tester. At least 10 specimens were observed at each tensioning load.

Observations for the most part were made under ordinary room conditions. A few samples, however, were observed at 276° F, with the humidity that of ambient room atmosphere at that temperature.

Results of Endurance Test

A typical set of observations is recorded in Table III for cord 4. In Figure 2, curves *A*, *B*, and *C* represent the observations on cords 4, 6, and 5 (Table I), respectively. When the time, *t*, during which a cord has sustained a particular tensioning load, was plotted as logarithm against the load, *l*, a linear relation was apparent. These lines are represented by the general equation

$$\log t = a - bl,$$

where *a* and *b* are constants whose approximate values are 12.0 and 0.13, respectively.

In Figure 3, curves *D* and *E* fit the plotted data for cords 7 and 8 (Table I). The observed points for these cords, as for those plotted in Figure 2, fall very closely on straight lines whose equations also follow the general equation with constants *a* and *b* having approximate values of 14.0 and 0.14, respectively.

In Figure 4, curves *F* and *G* (cords 1 and 2) show how commercial rayon tire cords endure under static tensioning at ambient room conditions. The relation between time, *t*, and tensioning load, *l*, up to rupture does not follow so closely the simple logarithmic relation found in the cotton cords. Curve *H* (cord 3, a commercial cotton cord) has been given for comparison.

The data plotted in Figure 5 depict some preliminary observations on cords 1, 2, 3, 4, 6, and 7 at 276°F. The extension of these curves to the tensioning-load axis would presumably intercept the latter at the breaking strengths of the corresponding samples, measured at the same temperature. The strengths at 276° F for several of the samples are indicated along the tensioning axis by the letters corresponding to the curves. The curves *I*, *J*, *K*, and *L*, representing the cotton cords 4, 3, 6, and 7, respectively, may, within experimental error, be considered straight lines as they are at room temperature. The curve *N* (cord 1) appears to have convexity away from the tension-

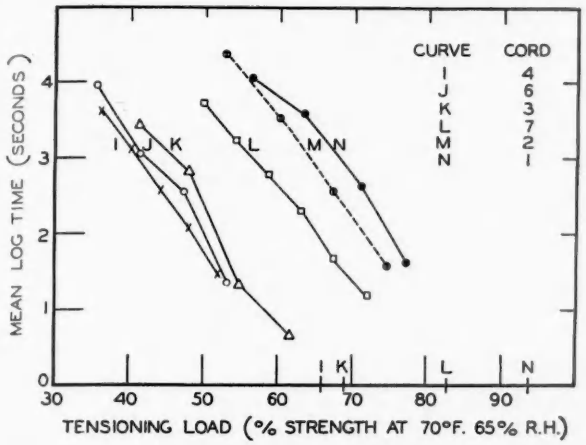

FIG. 5. *Logarithm of time under static tensioning at 276°F vs. load of tensioning. The hot breaking loads are indicated along abscissa with corresponding letters.*

ing axis. The curve *M* (cord 2), also a rayon cord, does not show this nonlinearity.

In Figure 6 is plotted the endurance of mercerized cord 8 at 276° F before and after stabilizing by heating at that temperature for 2 hours. Curve *R* represents cord when tension is applied 4 minutes after it has been placed in the oven. This curve, like curve *N* (Figure 5), has convexity away from the tensioning axis. When, however, the effect of change in

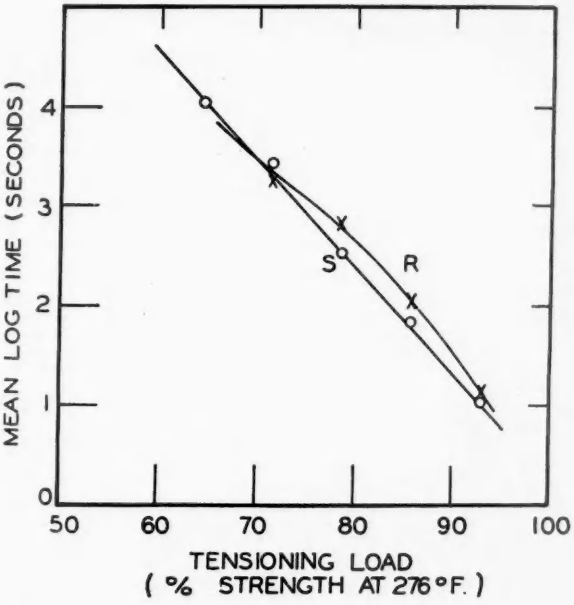

FIG. 6. *Logarithm of time under static tensioning vs. load of tensioning for experimental mercerized cord 8, r. before, and s, after, stabilizing by heating at 276°F for 2 hours.*

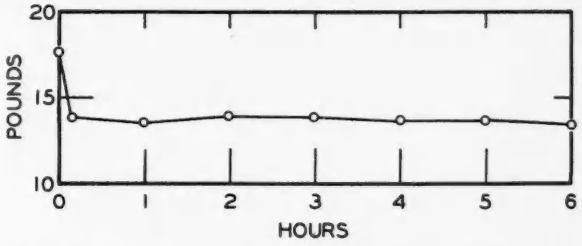

FIG. 7. *The change in strength of cotton tire cord 8 upon heating at 276°F.*

strength is obviated by preheating for 2 hours at 276° F, the endurance under static tensioning is represented by the straight line *S*.

This change in strength for cord 8 up to at least 6 hours of heating at 276° F is represented in Figure 7. No appreciable change takes place after the first 15 minutes.

Discussion

For cotton cords, the curves of relation between the tensioning load and the logarithm of the time elapsing under tension before rupture are straight lines at room conditions, within experimental error; but, for rayon cords at the same conditions, the curve appears slightly convex away from the tensioning axis. This nonlinearity would appear to be confirmed by unpublished data obtained in an investigation of flexure endurance being conducted by one of the present authors. In all instances the extrapolated extension of the curves denoting the relation intercept the tensioning axis at approximately 100 percent—that is, the breaking tension under standard testing conditions. These intercepts, however, represent the situation in which the breaking tension is applied for a time whose logarithm is 0, or for a time of 1 second, whereas in standardized techniques of strength determination using a pendulum-type tire-cord tester with A.S.T.M. specifications the time elapsing between the initial application of tension and the breaking of the specimen is appreciably greater than this.

The departure from linearity at 276° F shown by cords 1 and 8 is not infrequently noticeable in cords such as those of rayon and mercerized cotton the strength of which increases upon drying. This behavior is very likely to occur when moisture is not controlled and a change to a new equilibrium with water vapor may be taking place. Designation of tensioning load as percentage of a specimen strength at a single specimen condition, since obviously strength is changing during the interval of the en-

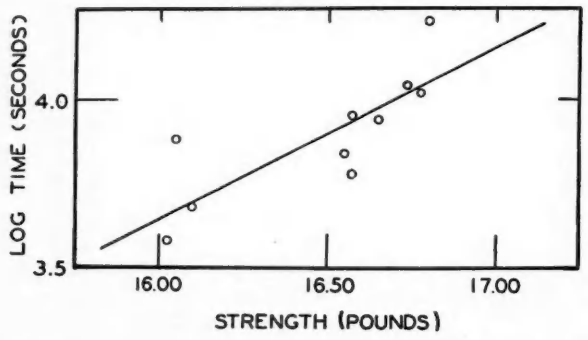

FIG. 8. *Logarithm of time under static tensioning vs. strength for 10 samples, 10 specimens each, taken from a bulk sample of cord 6.*

durance, will produce departures from the simple linear relation between logarithm of time and tensioning. Thus under the lower tensionings when the specimen is exposed for relatively longer periods to the higher temperature, the cord may be enduring with the strength that it possesses only at the higher temperature. Therefore, strength equilibrium as well as temperature equilibrium must be considered when tensioning is expressed in terms of one measurement.

Data reported by others suggest departures from the straight-line relation in cotton ropes and cords [5] and in metals [4, 7].

A consideration of the course of variations in strength in tire cords under static tension, as a factor in endurance, in effect supplies information concerning the stability of the specimen with respect to strength under the particular conditions. Thus it would be of great interest to determine the change of strength of the cord after various periods of subjection to the static tensioning load, as well as to examine the nature and amount of elongation as the cord under a relatively small tensioning load eventually reaches a state in which its strength has been so reduced that the small load ruptures it.

In view of the fact that strength is a fundamentally definitive factor in flexure endurance, its significance in relation to endurance under static tension is expected. As corroborative evidence, over 200 consecutive specimens were taken from a single sample of cord 6 (Acala 1517). Alternate specimens were used for tensile-strength determinations and 67 percent of the average strength found was used as the tensioning load for the remaining specimens. In Figure 8 are adduced the average results in groups of 10 observations taken consecutively from these two series of determinations. The range in average

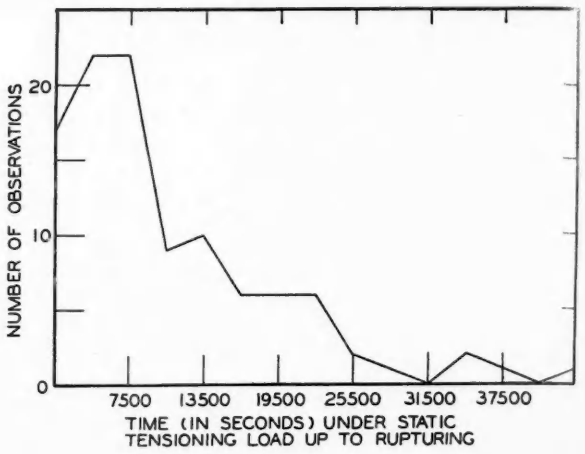

FIG. 9. *Relation between actual number of samples of cord 6 and their respective times of enduring under static tensioning; 106 observations.*

strength of the ten groups is from 16.0 to 16.8 pounds. Variation in time of endurance under static tensioning corresponds with the range in strength, the latter accounting for almost the whole range in durability. The average of all these observations is indicated on curve *B* in Figure 2. These considerations suggest the great practical importance of uniform strength as well as uniform stability of strength in the tire cord.

In addition to the change in strength, two other factors causing deviations in results are (1) jarring while cords are being placed under tension, and (2) variation in tensioning rate. At high tensioning load the time required to apply the tension is a measurable part of the time of endurance. Some of these effects are discernible in the coefficient of variation, which for many samples increases with increase in tension.

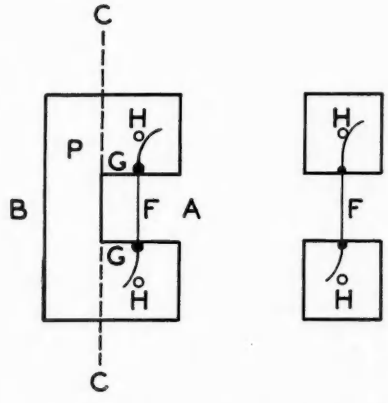

FIG. 11. *Method of mounting a single fiber for determination of strength. Fiber,* F, *is fixed to paper,* P, *having holes for mounting,* H, *with drops of glue,* G. *Bridge of paper,* B, *is cut off along line,* C.

TABLE IV. RANGE IN STANDARD DEVIATION FOUND AT VARIOUS TENSIONING LOADS FOR CORD 5

Load	Endurance	
Percent of strength at 70°F, 65% R.H.	Mean log (sec.)	Standard deviation (sec.)
55	5.47	0.43
62	4.67	0.34
69	3.90	0.23
76	2.98	0.31
83	2.45	0.43
90	1.16	0.45

In Table IV are given the deviations found for cord 5. The deviation in part, of course, results from the nonuniformity in the cord, plies, and yarns. Other factors causing deviations are variations of twist, diameter, nature and distribution of individual cotton fibers.

In applying the customary statistical techniques, it is important both to be certain that the variations in the property measured follow a probability distribution and that adequate account of departures is taken. Pursuant to this requirement the observations discussed above (Figure 8) are plotted in Figure 9 to show the manner of distribution when the actual time is taken as one of the variables. One break at 73,500 seconds is not shown. The resulting curve appears not to be of the nature of the normal probability curve. When, however, instead of the actual time in seconds the logarithm of the time in seconds is

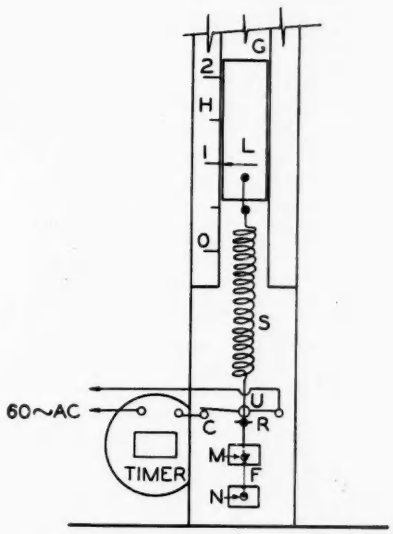

FIG. 12. *Apparatus for static-tensioning a single cotton fiber. Coil spring,* S, *attached to slide,* L, *for adjusting tension on specimen,* F, *with mounting holes placed on hook,* M, *and peg,* N. *Wire,* U, *and peg,* C, *are electric contacts in circuit to timing motor.*

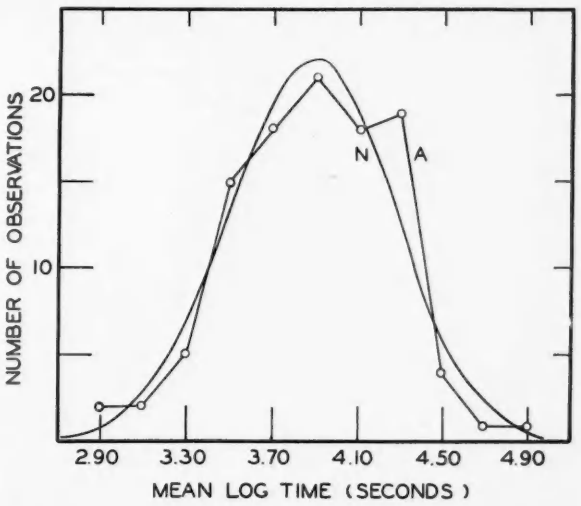

FIG. 10. *Relation between actual number of samples of cord 6 and logarithms of their respective times of enduring under static tensioning; 106 observations.*

utilized, as in Figure 10, curve *A*, the observations fall sufficiently close to a normal probability curve, *N*, to justify the analysis by ordinary statistical method of the data on static endurance. The logarithm of time, therefore, instead of actual time, would be expected where variations in strength expressed in units of time determine the distribution. Other measurements such as creep and rate of loading, also associated with static endurance tests, are usually expressed as a function of the logarithm of time. This corroborates the observations of Mann and Peirce [6].

Single-Fiber Measurements

It appears that the breaking of a cotton tire cord is a phenomenon of flow or creep. The question immediately arises as to whether the apparent flow in the cord consists merely of movement of fiber past fiber or of a movement in microscopic and submicroscopic structural elements in the fiber or filament. Results of measurements made on single fibers indicate that the same phenomenon of flow exists in the single fiber as in the cords fabricated from them.

Samples

For the strength and static endurance tests, the cotton fibers selected were from the same samples which were used to manufacture cords 4 and 5 (Table I), and were classified as 1.4-inch by Suter-Webb [2] length-array methods; the rayon filaments were removed from cord 1 (Table I) and were cut to 1.4-inch specimens.

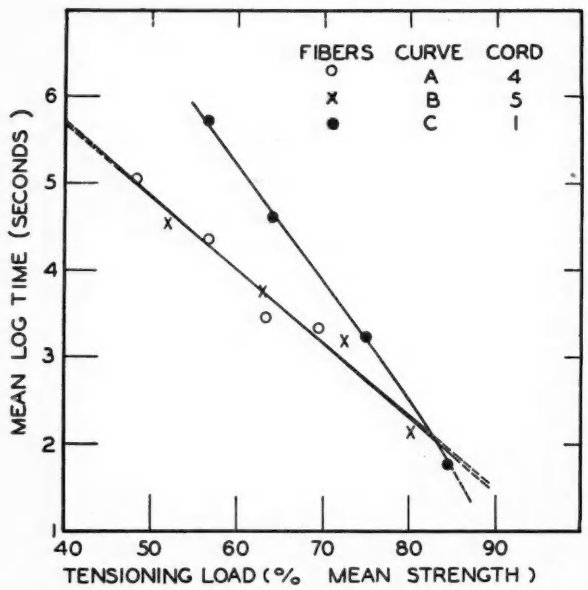

FIG. 13. *Logarithm of time under static tensioning vs. load of tensioning for single fibers of cords 4 and 5, and filaments of cord 1.*

Method

A single cotton fiber from the length group to be tested was placed on a paper mounting, as shown in Figure 11. Small drops of cement applied to the fiber and paper near the cut-out portion, *A*, fastened the fiber to the paper. When the cement had dried, the paper and the fiber were clamped beyond the cement in rigid parallel jaws for handling, while the bridge, *B*, was clipped off. The fiber, *F*, and mounting were placed in position on a tensioning device (Figure 12) by inserting a hook, *M*, attached to a spring, *S*, through one hole in the mounting, while a hole in the mounting attached to the other end of the fiber was placed over the peg, *N*.

The degree of tensioning, which may be altered by moving the slide, *L*, attached to the spring in groove, *G*, is indicated on the scale, *H*. When the specimen breaks, arm *R* catches wire loop *U*, to break the timer circuit at contact point *C*.

Tensions in excess of 80 percent of the average fiber strength were applied by the single-fiber tensile-strength tester so modified that it stopped at any desired tensioning. On this machine the timer circuit closes when the desired tension is reached, and opens when the fiber breaks. The average fiber strength was determined on a single-fiber tensile-strength tester from a minimum of 100 fibers at 70° F, with 65 percent relative humidity.

A minimum of 18 observations were made at each tensioning with a ¼-inch test-specimen length.

Results

The test showed such a wide variation in strength from fiber to fiber that the static tensioning chosen for a certain percentage of the average dynamic strength at 70° F, 65 percent relative humidity, may actually be a breaking tension for some of the fibers and a relatively very low tension for others. The fibers that had ruptured during the time the tensioning was being applied, or before the final set tensioning was reached, were eliminated, and the average dynamic strength was recalculated for all fibers whose dynamic strength was greater than the particular static tensioning used. This calculation is shown in Table V for fibers of cord 5 (Table I).

In Table VI are the results of the static tensionings of fibers whose mean strengths were the averages derived in Table V. The curves from fibers of cords 1, 4, and 5 are given in Figure 13.

Discussion

From a comparison of curves it is found that the relation of logarithm of time endured, *t*, and the percentage of tensioning load, *l*, for a single cotton fiber or rayon filament is the same type of relationship as that found in the cords constructed from these fibers or filaments. Since the curves representing the fibers approximate the curves for the cords, a similar phenomenon must exist in the breaking of both fiber and cord. These observations indicate that the phenomenon produced by tensioning of a fiber or cord is one of flow and not merely one of slippage of fibers past fibers. A slight movement of fiber past fiber which undoubtedly occurs during elongation, resulting from application of the load, probably terminates prior to the actual breaking phase. When rupture of part of the fibers in a cord has taken place, further movement of fibers which may then recur would obviously have little effect on endurance.

Summary

As an aid in the further interpretation of tests of the endurance of tire cords under conditions of flexing, tests were made of endurance under static tensioning. The samples measured represented the following types of tire cord: regular commercial rayon and cotton cords; experimental cotton cords manu-

TABLE V. MEAN STRENGTH OF ALL FIBERS ABOVE A GIVEN STRENGTH. CALCULATED FROM STONEVILLE 2B FIBERS 1.4 INCHES LONG; BROKEN AT ABOUT 50% R.H. AND 75°F. LENGTH OF SAMPLE TESTED, ¼ INCH. MEAN STRENGTH, 5.09 GRAMS

Grams	St Strength group	P Distribution %	ΣP	St × P Grams	Σ(St × P) Grams	Σ(St × P) / ΣP Grams	Mean strength %
0–1	(0.5)	0	100	0.0	509.0	5.09	9.8
1–2	(1.5)	2	100	3.0	509.0	5.09	29.5
2–3	(2.5)	11	98	27.5	506.0	5.16	48.5
3–4	(3.5)	19	87	66.5	478.5	5.50	63.7
4–5	(4.5)	21	68	94.5	412.0	6.06	74.3
5–6	(5.5)	18	47	99.0	317.5	6.77	81.3
6–7	(6.5)	13	29	84.5	218.5	7.55	86.0
7–8	(7.5)	7	16	52.5	134.0		
8–9	(8.5)	5	9	42.5	81.5		
9–10	(9.5)	3	4	28.5	39.0		
10–11	(10.5)	1	1	10.5	10.5		
11–12	(11.5)	0	0	0.0			

factured and mercerized at the Southern Regional Research Laboratory; and mercerized and unmercerized cotton cords from a selected variety manufactured on standard commercial equipment. The curves of relation between the tensioning load and the logarithm of the time elapsing under tension before rupture were plotted from data obtained in typical observations made over a range of tensioning load of from 50–90 percent of the previously determined tensile strength of the cords.

For cotton and rayon cords the relation between the static tensioning and the logarithm of time up to rupture—that is, of the time during which the load is sustained—is inverse with tensioning load. For unmercerized cord the relation is linear over a range in time from 10 seconds to 3 weeks at room temperature and 10 seconds to 1 hour at 276° F. For rayon cord a linear relation was not found at either temperature; lines through the observed points are concave as observed from the origin. A similar nonlinear relation was found at elevated temperature for mercerized cotton cord. Where linear relation exists the curves extrapolated to intersect the load axis at log 0 will approximate the tensile strength of that cord when determined under the same temperature condition as that of the endurance test.

Fibers from the cotton used to construct the cords and filaments removed from the rayon cords show similar relationships between load and logarithm of time as those found in the cords—that is, the relationship is linear for cotton and curved for rayon. An equation representing the rayon filament will differ from that for the cord by a constant, whereas the cotton fiber will differ in both the slope and the constant. The breaking under static tensioning in the single cotton fiber and the rayon filament is a phenomenon of flow of the micro-elements in the fiber. A similar relation exists in the cord, indicating that the rupture of the cord is the flow in the fibers or filaments and not merely one of movement of fiber past fiber. Breaking is the terminal condition of this phenomenon of flow.

TABLE VI. LOGARITHM OF THE TIME OF ENDURING UNDER DIFFERENT TENSIONS FOR SPECIMENS ¼ INCH LONG FROM FIBERS 1.4 INCHES LONG, OF STONEVILLE 2B, 1943, COTTON WITH STAPLE LENGTH 1 3/32 INCHES

No. of observations	Av. log of life	Load	
		Absolute g.	Mean strength (%)
34	5.01	2.5	48.5
48	4.38	3.0	56.5
21	3.47	3.5	63.7
18	3.35	4.0	69.5

Acknowledgment

The writers wish to express their indebtedness to members of the Cotton Chemical Finishing Division and Cotton Processing Division for the experimental cords, and to Ora Morlier and Mary Rhodes, who performed much of the experimental work.

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Correction

In the paper entitled "Manufacture of Tire Cords from Spun Rayon Yarn" by K. Kobayashi, which appeared in the October, 1946, issue, in Table II, page 501, under the heading "Cotton cord" the figure for "Cleaving test" should be 100% instead of 150%.

Natural and Synthetic Protein Fibers*

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Introduction

Full realization of the fact that textile fibers are for the most part made of fibrous molecules has undoubtedly been one of the major factors contributing to the present activity in the field of synthetic fibers. Considering the great variety of natural and synthetic polymeric molecules which are potential fiber-formers, it does not appear likely that this activity will diminish in the near future. One group of such molecules that has excited much interest recently from the point of view of fiber production is found in the proteins. Thus, fibers have been spun from such proteins as casein, soya bean, peanut, zein, collagen, chicken-feather keratin, egg albumin, gliadin, blood serum, etc., and at least several are being produced commercially [5, 22]. These fibers, like the early cellulosic rayons, have somewhat low wet strengths and this, among other factors, has given rise to speculation concerning the possible place of such fibers in future textile economy. The answer to such questions must be sought in considerations of the important properties of textile fibers and the dependence of these properties on the structure of the fiber molecules.

At the outset, it is appropriate to mention a few generalizations concerning fibers and their parent class of materials, the organic high polymers. The great industrial importance of nearly all organic high polymers arises from their wide range of mechanical properties. Thus, rubber is important because of its long-range elasticity, and resins can be formed into materials of considerable strength or so modified as to yield systems of considerable flexibility or elasticity, whereas textile fibers have a great variety of properties which lend themselves well to the fabrication of materials ranging from women's hose to heavy industrial fabrics. In many cases, only a small difference in chemical structure may determine whether a material is a rubber, a plastic, or a fiber. The close similarity of these systems was recently emphasized by Mark [14], who advanced the following general qualitative scheme for predicting the mechanical behavior of organic high polymers:

If the polymer molecules fit poorly into a lattice and the intermolecular attractions are weak, then the material should have rubber-like properties. In contrast, if the structure of the molecules permits easy fitting into a lattice and the forces between molecules are strong, the material is a fiber. In intermediate cases, plastic systems result.

In several respects, such a qualitative classification is equally useful, or even more so, for classifying different fiber systems. For example, if the molecules fit readily into a lattice and the intermolecular forces are numerous and strong, a very strong, relatively rigid fiber, with very short-range elasticity, is obtained (cotton, ramie, Fortisan, high-tenacity rayon, etc.). If the molecules fit poorly into a lattice and the intermolecular forces are weak a fiber of lower strength but greater extensibility results, whereas if the molecules are flexible, the fiber can exhibit long-range elasticity (wool, elastic nylon, Vinyon E, etc.). Finally, for intermediate cases where the intermolecular forces are weak or there are relatively few strong ones, fibers with an intermediate range of elasticity and a wide range of strengths are obtained (nylon, silk, Vinyon, cellulose-acetate rayon, etc.).

Although much information must still be acquired in order to improve the quantitative aspects of such a classification, a picture has been developed sufficiently to form a basis for considering the possible future in the utilization of various polymer molecules in general, and protein molecules in particular, for producing textile fibers. This concept becomes especially useful when used in conjunction with an

* Presented at a Symposium on Fibrous Proteins held at the University of Leeds, England, May, 1946, and sponsored by the Society of Dyers and Colourists. Reprinted from the bound volume *Fibrous Proteins*, containing the papers in the Symposium, by permission of the Society of Dyers and Colourists.

analysis of the two most important natural protein fibers, wool and silk.

Wool and Silk

From the classification just described, it is apparent that wool and silk belong to somewhat different categories with respect to mechanical properties, wool being characterized by long-range elasticity and moderately low strength, whereas silk possesses much greater strength but a much lower range of elasticity. The basis for these differences is found in the nature and structural arrangement of the molecules of the two types of proteins.

Silk

Perhaps the most distinguishing feature of silk is found in its amino-acid composition as shown in Table I. More than 80 percent of the amino-acid residue weight is accounted for by three amino acids of low molecular weight, *viz.*, glycine, alanine, and serine. The polypeptide chains of silk may be considered to be essentially bare or "naked"—that is, they contain relatively few bulky side-chains. This immediately suggests that segments of the polypeptide chains lend themselves to close packing and that considerable inter-chain hydrogen bonding is possible, and indeed this appears to be the case. X-ray [7] and birefringence studies both show a relatively high degree of orientation and crystallinity in the fiber, estimates indicating about 40–60 percent of crystalline material. Presumably, the crystalline regions consist primarily of the small amino acids glycine, alanine, and serine, but these regions cannot accommodate amino acids with bulky side-chains, such as tyrosine, which apparently give rise to the "amorphous" regions. The fiber diagram for silk has also been interpreted to be that of a stretched or fully extended polypeptide chain [16].

On the basis of this structure, the desirable properties of silk are readily explainable. The hig strength, both wet and dry, is due to the extende chains, the high degree of orientation and crystallinity,

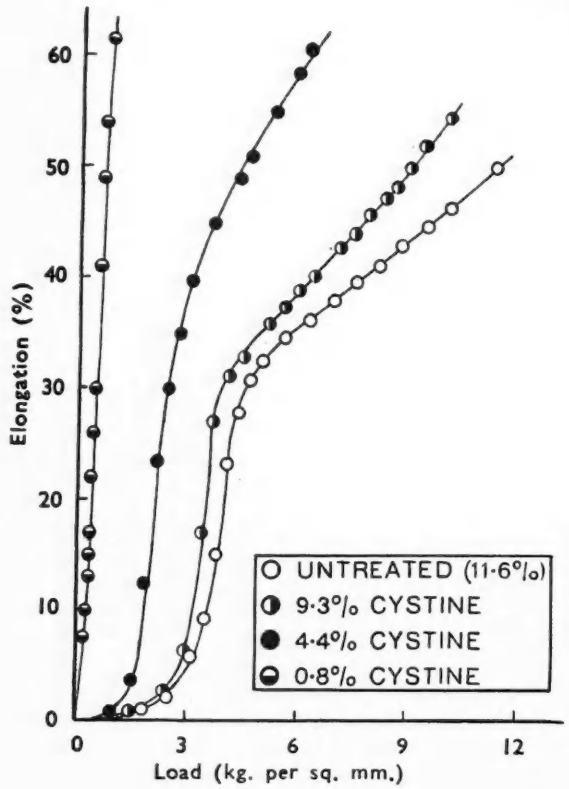


FIG. 1. *Load-elongation curves for wool fibers which have been reduced with calcium thioglycollate and then methylated with methyl iodide. The fibers were stretched to the break while immersed in water. The fibers of 0.8 percent cystine content broke at 97 percent elongation; the others broke at the elongations shown.*

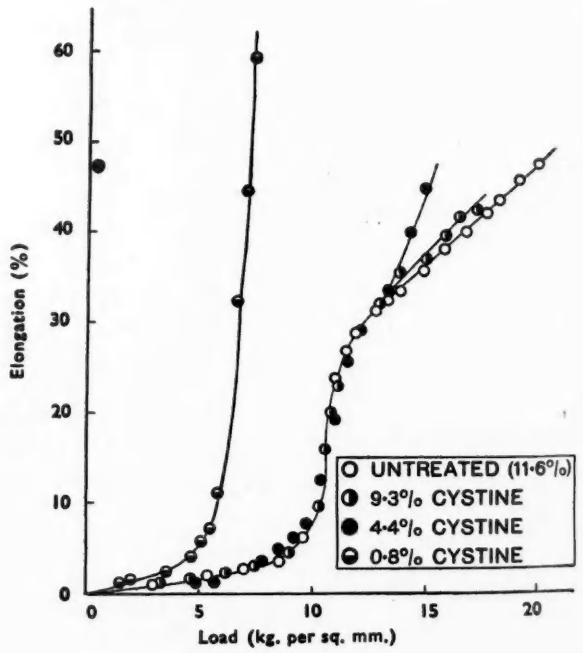


FIG. 2. *Load-elongation curves for wool fibers which have been reduced with calcium thioglycollate and then methylated with methyl iodide. The fibers were stretched to the break at 65 percent R.H. and 70°F. The fibers of 0.8 percent cystine content broke at 87 percent elongation; the others broke at the elongations shown.*

TABLE I. AMINO-ACID COMPOSITION OF WOOL AND SILK FIBROIN

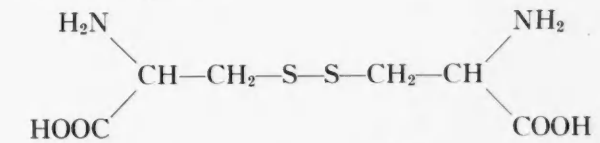
	Percent present in wool [12]	Percent present in silk fibroin*	g. per 100 g. wool		g. per 100 g. silk fibroin	
			Residue	Side-chains	Residue	Side-chains
Glycine	6.5	44.4	4.94	0.09	33.74	0.59
Alanine	4.4	26.4	3.52	0.74	21.06	4.45
Serine	9.41	13.5	7.80	2.76	11.21	4.08
Proline	6.75	—	5.69	2.46	—	—
Valine	4.72	—	3.99	1.73	—	—
Threonine	6.76	1.6	5.74	2.59	1.36	0.61
Cystine/2†	12.72	0.0	10.83	4.89	0.0	0.0
Leucine isomers	11.3	0.9	9.75	4.92	0.78	0.39
Aspartic acid	7.27	—	6.28	3.22	—	—
Lysine	3.3	0.3	2.89	1.63	0.26	0.15
Glutamic acid	15.27	—	13.40	7.58	—	—
Methionine	0.71	0.0	0.62	0.36	0.0	0.0
Histidine	0.7	0.07	0.62	0.37	0.06	0.04
Hydroxylysine	0.21	—	0.19	0.11	—	—
Phenylalanine	3.75	1.5	3.34	2.07	1.34	0.83
Arginine	10.4	0.7	9.33	5.97	0.63	0.40
Tyrosine	5.8	13.2	5.23	3.43	11.88	7.80
Tryptophane	0.7	—	0.64	0.45	—	—
Total	110.67	102.57	94.80	45.37	82.32	19.34
Ammonia N	1.18		0.30	0.30	—	—
Total, corrected for ammonia N			94.50	45.07	82.32	19.34

* Taken from Block and Bolling, *Determination of the Amino Acids*, revised ed., Minneapolis, Burgess Publishing Co., 1945.
† Based on 3.55% total S, subtracting methionine-S.

and the strong bonds which can be formed between neighboring —CO·NH— groups.* The elasticity and extensibility depend upon chain mobility in the amorphous regions. Because the chains are more or less fully extended, both the elasticity and the extensibility are necessarily relatively short-range in magnitude.

Wool

In contrast with silk, the proportion of low-molecular-weight amino acids in wool is very small (20 percent approximately); in other words, practically all the amino acids are of the type that give rise to large, bulky side-chains and, as shown in Table I, nearly 50 percent by weight of wool protein is in the side-chains. Close packing of such molecular chains would be difficult, and it would accordingly be expected that wool fibers should exhibit relatively low tensile strengths; this expectation has been borne out by experiment [15]. In addition, its diversity of side-chains makes it necessary to consider the keratin molecule as an extremely complex copolymer, a system which should be incapable of forming "crystallites" to any appreciable extent, and this expectation has also been confirmed experimentally [4]. However, it must be pointed out that owing to the preponderance of polar groups, such a system would have especially low wet strength were it not for wool's (and other hairs') most distinguishing chemical characteristic, the presence of a relatively high percentage of cystine—



Although cystine contains two amino and two carboxyl groups, it appears that all these groups are involved in peptide links [18]; hence cystine must form part of two polypeptide chains and its disulfide group becomes a connecting or cross-link. Astbury and Street [3] were the first to point out the presence of such links; since then, Astbury, Speakman [21], and other workers in this laboratory have provided evidence supporting their existence.

* In this respect silk resembles nylon. A major difference is that in nylon these groups are separated by hydrocarbon segments (generally, four or more —CH_2— groups). The elasticity of nylon presumably arises from the rubber-like elasticity of these segments.

Earlier work [11] involving rupture of rebuilding of these cross-links emphasized the dependence of such properties as wet strength, resistance to plastic flow, etc., on the disulfide cross-links. The results of additional studies, designed to obtain a more quantitative picture of this relationship, are given below. The experimental procedure used was as follows:

Various proportions of the disulfide cross-links were reduced with calcium thioglycollate and permanently ruptured by methylation [10]; the load-elongation characteristics of the fibers, before and after modification, were then determined [12]. Since the purpose of these experiments was to evaluate more precisely the contribution of the cross-links, most of the load-elongation measurements were made on wet fibers, because in the wet state the fiber is swollen and, consequently, the contribution of secondary forces acting between neighboring polymer chains approaches a minimum. That such measurements are more sensitive to changes in the number of linkages ruptured, compared with measurements on conditioned fibers (65 percent R.H.; 70°F), is shown in Figures 1 and 2.

In Figure 1, a fiber stretched while wet shows diminished resistance to elongation, as well as a decreased modulus of elasticity with decrease in cystine content. Since decrease in cystine content is a direct measure of the number of disulfide cross-links ruptured, the marked dependence of mechanical properties on cross-links is again demonstrated. When the load required to stretch the fiber 25 percent is plotted against cystine content (Figure 3), it is noted that as the number of cross-links increases the strength goes up rapidly, but when about half the cross-links are present, further gains in strength are proportionately smaller.

In contrast with the strength of wet fibers, that of conditioned fibers does not show the same direct dependence on cross-links (Figure 2). As the cystine content decreases—that is, as the number of cross-links decreases—there is little change in the stress-strain characteristics until a large proportion of cross-links are ruptured. This can be taken to indicate that in conditioned fibers the preponderance of secondary forces far overshadows the contribution of the relatively few covalent cross-links. The very different behavior of the sample in which the cystine content has been reduced to 0.8 percent is believed to result not only from rupture of cross-links but probably from other changes made possible by the excessive swelling which occurs during reactions severe enough to rupture most of the links.

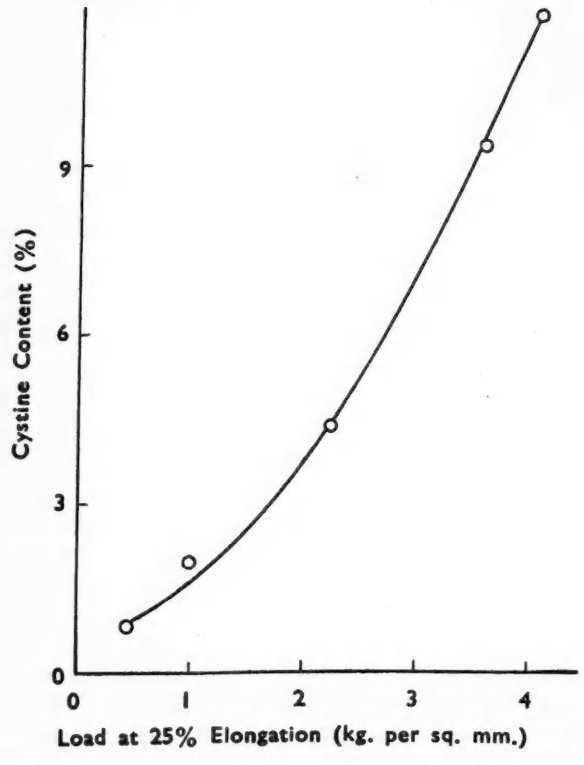


FIG. 3. *Relationship between cystine content, which is proportional to the number of cross-linkages present, and load necessary to extend reduced, methylated wool fibers 25 percent of their original length while immersed in water.*

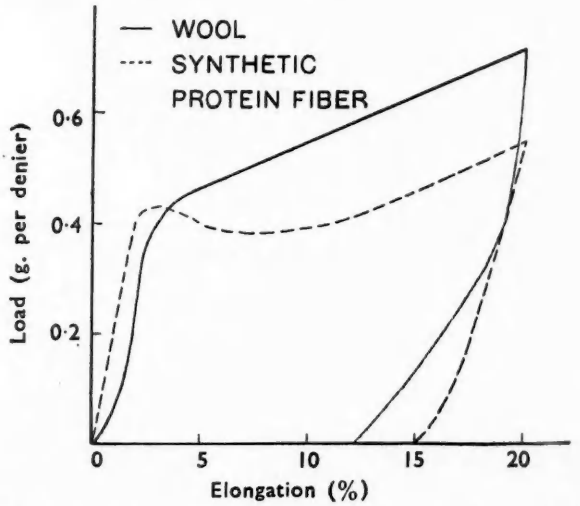


FIG. 4. *Load-elongation cycles for wool and synthetic protein fibers which were elongated 20 percent and then returned at a constant rate. The experiments were carried out at 65 percent R.H. and 70°F.*

The combination of factors such as the inability of wool to crystallize, the well-known flexibility of protein molecules, and the presence of covalent cross-links to supply strength as well as to diminish plastic flow [12], form the basis for what is now recognized to be one of the most important mechanical properties of wool—*viz.*, its long-range elasticity. Apparently, as first emphasized by Astbury and Woods [4], the keratin molecule in the native fiber exists as relatively highly folded chains which on application of stress become more or less fully extended; the elastic characteristics presumably depend on the ability of the flexible chain molecules to contract from the less probable extended state to a more random form. In this respect wool appears to be somewhat analogous to rubber [12].

Synthetic Protein Fibers

The foregoing discussion suggests that at least two distinct "models" are available as patterns for the production of synthetic protein fibers; they may be referred to as the "silk model" and the "wool model." The former requires molecules which extend readily and are made up of such monomeric units that a major part of the segments of the molecules are able to fit into "crystalline" areas, whereas a limited portion of the segments contain bulky side-chains which give rise to "amorphous" regions. By anchoring the chains in the crystalline areas, the strength, and more especially the wet strength, remains high; the amorphous regions make possible chain mobility, which accounts for a limited range of extensibility and elasticity. The wool model requires chains which do not crystallize and so tend to be more or less folded; in this case, the chains must be anchored at intervals by covalent cross-links to supply strength and prevent plastic flow.

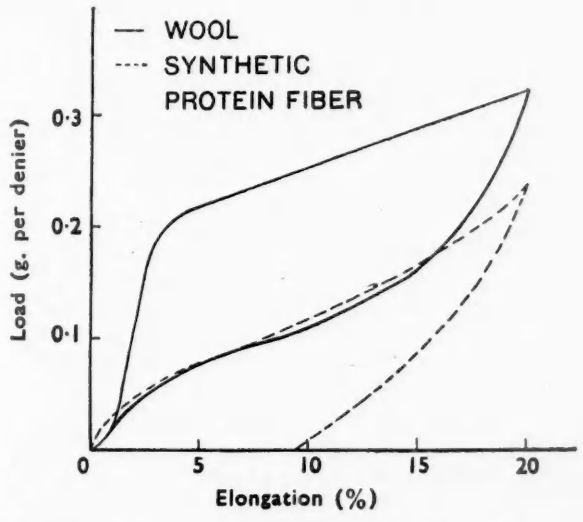


FIG. 5. *Load-elongation cycles for wool and synthetic protein fibers which were elongated 20 percent and then returned at a constant rate. The experiments were carried out with the fibers immersed in water.*

Whether either of these models can be approached in actual practice will depend on the chemical structures of the proteins, the ease with which the flexible protein molecules are transformed from their natural configurations to an optimum configuration for fiber construction, and the extent to which these configurations can be stabilized in the fiber. These factors are discussed briefly in the sections immediately following.

Chemical Structure

An enormous amount of work has been done on the quantitative estimation of the amino acids in the various proteins, but little can be said with certainty regarding the arrangement of the amino acids in the polypeptide chain. Nevertheless, the data clearly indicate that all the proteins studied in relation to synthetic protein fibers, and, indeed, practically all important protein materials, are made up largely of amino acids with bulky side-chains. In fact, the weight of the side-chains in many instances—for example, in wool—is about 50 percent of the weight of the material. In other words, the possibility of fabricating from these materials a structure based strictly on the "silk model" principle appears quite remote. Fibers from ordinary proteins can be highly oriented by stretching in water or steam to 400–600 percent of the original length [8, 13, 19] and the dry strength accordingly increased. However, water readily penetrates practically all parts of such structures and since the chains, unlike those in silk, are not anchored in crystalline regions, the fibers suffer marked losses in strength when wetted. Presumably, anchoring of the chains might be accomplished when suitable cross-linking techniques become available. These considerations, preliminary though they may be, strongly suggest that the available proteins (other than silk) should lend themselves more readily to the wool model structure, and evidence bearing on this is presented later in this paper (page 329).

It should be emphasized at this point that the nature, number, and distribution of the side-chains of the constituent amino-acid residues of the polypeptide chains will undoubtedly have a profound effect on the

TABLE II. COMPARISON OF SOME MECHANICAL PROPERTIES OF PROTEIN FIBERS

Sample	Condition	Residual elongation* (%)	Young's modulus (g. per denier/%)	Load at 20% elongation (g. per denier)
Wool, domestic†	wet	0.0	0.10	0.32
	dry**	12.0	0.22	0.72
Silk, degummed†	wet	13.6	0.26	3.27
	dry	‡	0.74	‡
Peanut§	wet	7.0	0.027	0.25
	dry	15.0	0.25	0.54
Casein§	wet	9.0	0.016	0.11
	dry	15.5	0.24	0.44
Soya bean§	wet	8.0	0.006	0.05
	dry	‡	0.28	‡
Egg white§	wet	‡	0.006	‡
	dry	‡	0.34	‡
Zein§	wet	9.5	0.036	0.21
	dry	15.5	0.23	0.57

* Temporary set of the fiber when zero load is reached during the constant rate of relaxation.

** Conditioned at 65% R.H. and 70°F.

† These values were obtained with the samples studied on our apparatus. A range of values was recently described [15].

‡ Fiber broke before extension to 20% of its original length.

§ Experimental fibers representative of recent fibers produced. It is not implied that these values are applicable to all fibers made from these proteins, especially since various treatments change fiber properties somewhat. Rather, these results for the specific fiber samples studied serve to show the range of values obtained in comparison with wool and silk.

manner in which segments of the polypeptide chains fold [2, 17]. Accordingly, it should be expected that such variations in structure will also influence the mechanical properties of the fiber, but the nature of this relationship still remains to be elucidated.

Manipulation of Protein Molecules

From the point of view of synthetic fibers, perhaps the most significant difference between proteins and cellulose lies in the relative rigidities of the molecular chains. The cellulose molecule is relatively rigid, more or less fully extended, and fits readily into a crystalline structure. In fact, the regeneration of cellulose in an "amorphous" form is extremely difficult. These factors greatly simplify the problem of converting cellulose into fibers. In contrast, most native proteins have folded corpuscular structures which are not desirable for fiber formation, and the problem becomes one of transforming these highly folded or coiled configurations to a more or less linear state in order to construct fibers with desirable mechanical properties.

Fortunately, most native proteins readily exhibit a phenomenon known as denaturation. The process is accompanied by decreased solubility of the protein, increased viscosity of the solution, and, most important, under suitable conditions results in the formation of fibrous molecules. The importance of this phenomenon for fiber formation has been emphasized by Astbury [1], and more recently by Senti [19], and Lundgren and coworkers [13]. Denaturation is induced by many agents—for example, heat, ultraviolet light, acids, bases, urea, guanidine, detergents, etc. Some of these agents not only denature the protein, but also tend to keep the molecules more or less fully extended; when the environmental effects of the denaturing agents are removed, the molecules tend to revert to a more highly folded configuration. The principle of utilizing a restraining influence which favors the existence of the protein chains in a less folded configuration has been successfully applied to this fiber problem by Lundgren and coworkers. Complexes formed between proteins and detergents, such as alkyl sulfonates or sulfates, acquire plastic flow properties which lend themselves well to the production of fibers. By this procedure, fibers of unusually high degrees of orientation have been prepared.

At present, however, very little can be stated about the actual shape of protein molecules, especially as it exists during spinning of the fibers. In most cases, molecular weights have been determined, and then, by assuming an average amino-acid residue size, the lengths of the molecules have been calculated. It must be emphasized that this calculation gives the intrinsic length, but what is really needed is what may be termed the "effective" length—that is, the extent to which the molecule is elongated. It appears certain that practical processes for suitably restraining protein molecules in linear form should greatly influence the development of synthetic protein fibers, and this appears to be a lucrative field for investigation.

Stabilization of the Fiber

The fact that there do not appear to be any proteins, other than those of the silk type, with chemical structures (naked chains) such that they can be self-stabilized by anchoring portions of the molecular

chains in crystalline regions, makes it necessary to utilize other means of stabilization. Hitherto, resort has been made to two types of chemical treatments, one which presumably cross-links the chains, and the other which diminishes the protein's affinity for water by converting hydrophilic to hydrophobic groups. In the forefront of the former type of treatment has been the reaction with formaldehyde, which decreases swelling and increases the wet tensile strength. The literature on this reaction is extensive [9] and indicates that not all the possible reactions of formaldehyde with proteins are clearly understood; nevertheless, evidence from the mechanical behavior of treated fibers suggests that at least some of the formaldehyde which reacts with the protein is involved in cross-linking. Typical of the second type of treatment is the well-known acylation of proteins, which increases the resistance of the fiber to the deleterious action of water [5, 6]. At best, however, the wet strengths of these fibers are still low compared with that of wool, and will undoubtedly be improved, probably by more efficient manipulation of the protein molecules before and during spinning and by more effective cross-linking methods.

The present picture leads to the conclusion that the pattern for the production of synthetic protein fibers must be the wool model, and further evidence favoring this view is provided in the next section.

Comparison of Some Mechanical Properties of Natural and Synthetic Protein Fibers

In order to facilitate comparison of the mechanical properties of various fibers, load-elongation curves were determined using the Sookne-Harris Fiber Extensometer, a recent modification of an autographic, constant-rate-of-elongation apparatus previously described [20]. Fibers 2 inches long were stretched at 0.2 inch per minute to 20 percent of their original length and then allowed to contract at the same speed. The results are summarized in Table II, illustrated by Figures 4 and 5.

Perhaps the most striking feature of the data is the general similarity in behavior of conditioned wool and synthetic fibers (Figure 4). In contrast with this is the wide difference in behavior of the same fibers when wet (Figure 5); under these conditions, the synthetic protein fibers exhibit a very low Young's modulus, decreased resistance to extension for a given load, a decreased Hooke's-law region and, finally, they do not recover their original length on removal of the applied load. It is interesting to consider the possible reasons for the similarity of these fibers when dry and their marked dissimilarity when wet.

It is evident from Figure 2 that, as the number of cross-links is appreciably reduced, there is only a slight change in the stress-strain behavior of the conditioned fiber. This has been interpreted to mean that, under these conditions of test, the secondary forces predominate, and presumably similar forces are active between polypeptide chains in both wool and the synthetic fibers. On the other hand, the curves in Figure 1 show the marked dependence of the desirable properties of wet wool fibers on the number of cross-links. More detailed examination of these curves shows that precisely the same properties which are characteristic of wet synthetic protein fibers—for example, a decreased Hooke's-law region, a lower Young's modulus, and decreased resistance to extension—are shown by wool fibers with ruptured cross-links. Thus, by working in reverse—that is, by "de-cross-linking" or "devulcanizing" wool—fibers with properties similar to those exhibited by synthetic protein fibers are produced. By analogy, therefore, it appears that the deficiencies exhibited by the synthetic protein fibers when wet may be attributed to the lack of sufficient, effective cross-links, and that the development of synthetic protein fibers with mechanical properties comparable to those of wool must await, in part at least, the development of more effective cross-linking techniques.

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Studies of the Treatment of Cotton in Sliver Form*

I. Effect of Syton: Spinning Studies

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Contribution from the Research Division of the National Cotton Council of America and the Bureau of Industrial Chemistry, University of Texas, Austin, Texas

MUCH has appeared in the literature during recent years concerning resin finishing of various textile materials. Although a large amount of work has been done in the modification and improvement of fabric properties through finishing treatments, the possibility of applying such treatments to cotton fibers prior to spinning has received little attention.

In a limited number of instances the treatment of unspun or partially spun fibers has been proposed for producing modified yarns [1–3] or nonwoven fabrics [4–7], but in these cases no subsequent drafting process was carried out. Three references were found to the treatment of unspun fibers with resins, followed by conventional spinning procedures. Two of these [8, 9] dealt with application at the spinning frame, and the third [10] involved the treatment of sliver or tow with a urea-formaldehyde condensate for the fixation of print dyes.

The work herein described was stimulated both by the possibilities inherent in applying textile finishes to fibers rather than to yarn or fabric and by the dearth of published results in the field, as noted above. Many textile finishes suffer in quality because of a lack of durability or of a change in fabric "hand." This poor performance in many instances may be related to the fact that the finish is physically, rather than chemically, bonded to the fibers, and it seemed logical to assume that if cotton fibers could be treated prior to spinning and weaving a more satisfactory physical distribution of the finish could be effected in the final textile product.

Development and Testing of Apparatus

After some consideration of the point of application of the treatments, the sliver state was selected. The possibility of a continuous single-strand treatment was particularly attractive from the standpoint of ease of rapid drying of the treated fibers for laboratory tests, and the uniform curing of resins involving this type of treatment.

An apparatus which was quite satisfactory in the laboratory-scale treatments used was evolved after some experimentation. It consisted of a stainless-steel impregnation bath, a pair of squeeze rolls, a drying section, and a coiler head for repackaging the treated sliver in standard 12-inch roving cans.

While the method of immersing, squeezing, and drying of sliver is admittedly not at present a practical method of mill application of synthetic resins or other treatments, it afforded a rapid and convenient means for the laboratory investigations which were undertaken. The sliver-treating apparatus had a capacity of from 5 to 10 pounds of cotton per hour, and was therefore practical for the preparation of the rather large samples used in the product evaluation studies to be described in a succeeding paper.

Sliver was conducted to the impregnation bath through a pigtail made from $\frac{5}{16}$-inch copper tubing, and was held beneath the surface of the treating liquid by means of two glass immersion rods, placed at opposite ends of the bath, which were the shape of an inverted U. It has been found that the immersion rods need not be free to rotate; the rotation of such a surface against the sliver tends to remove the loosely held fibers, and the immersion rods remain clean if the sliver is permitted to rub

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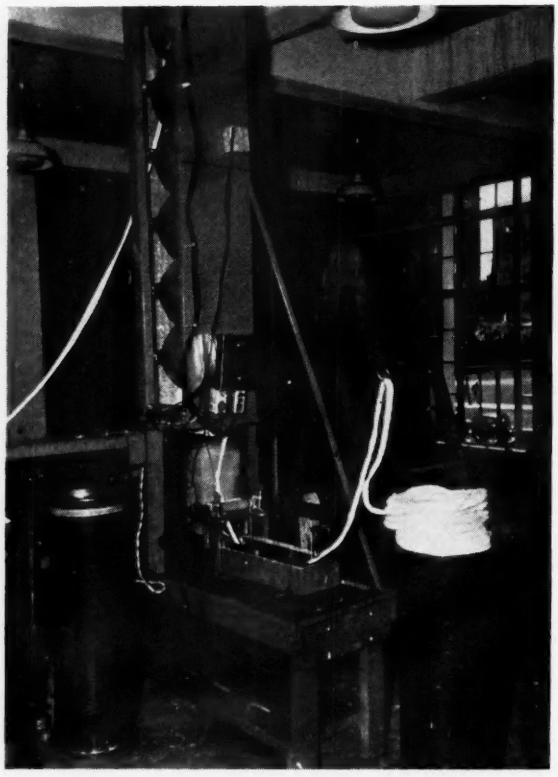

FIG. 1. *Sliver impregnator, showing bath with immersion rods, squeeze rolls, drying tunnel, and electrical controls. Constant level bottle is not shown.*

across them, continuously removing any fibers which might tend to accumulate. Immersion rods of at least $\frac{1}{4}$-inch diameter are necessary to prevent the accumulation, and rods of $\frac{3}{8}$-inch diameter or more are desirable. Small test tubes (75×10 millimeters) bent to the desired curvature to maintain the sliver in a central position in the bath have been found to be quite satisfactory.

The squeeze rolls employed were mounted in the frame of a Lovell wringer, and squeeze was controlled by spring loading. The rolls were mounted in the apparatus with their axes in a horizontal plane to minimize adherence of fibers to their surfaces, and were placed directly under the drying tunnel.

After some consideration of the various possible methods of drying the treated sliver, it was decided to utilize electrical infrared energy rather than hot air. The possibility of concentrating a considerable amount of energy output in a small space was attractive from the standpoint of economy of laboratory space, and equipment for the purpose was already at hand.

Two North American Lamp Company 7-lamp banks, equipped with $10\frac{1}{4}$-inch gold-plated reflectors and Type G-30 375-watt drying lamps, were mounted on opposite sides of a tunnel $80 \times 11 \times 14$ inches. The 14-inch sides of the tunnel were covered with 26-gage galvanized sheet steel. The distance between lamp banks could be varied by means of adjustable supports, thus providing a means for varying the intensity of radiation, and the positions of the lamps in the opposing banks were staggered to furnish as uniform a heat distribution as possible. One of the reflector-lamp units at the bottom of the tunnel was later replaced with a Type R-40 internal reflector lamp for ease in repairing sliver breaks in the tunnel.

To obtain the maximum drying capacity, a multipass arrangement was used in the tunnel. Rolls were provided at the top and bottom of the tower over which the sliver passed; the top roll was driven and the lower roll was allowed to idle. Separator rods were placed at the top and bottom of the tunnel to prevent entanglement of the various sliver strands, and with this arrangement the sliver could be con-

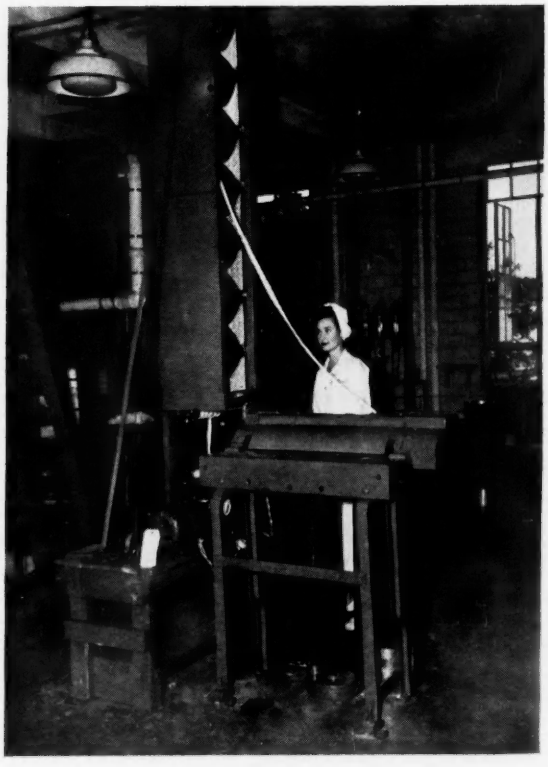

FIG. 2. *Modified sliver impregnator, showing drive, coiler head, and drying tunnel.*

TABLE I. RESULTS OF DRYING TEST

Lamp bank spacing—5½ inches; lamps used—13 Nalco-type G-30 375-watt, 1 GE-type R-40 250-watt; reflectors—13 gold-plated, 1 internal

Run	Passes in tunnel	Speed of sliver (ft./min.)	Time in tunnel (min.)	Moisture content, weight percent of dry cotton: Leaving squeeze rolls (%)	Leaving drier (%)
32*	0	12.1	0.00	70.2	—
33	11	12.1	6.39		0.07
34	11	14.1	5.37		0.03
35	11	17.0	4.66		0.02
36	11	20.0	3.80		0.17
37	11	24.0	3.18		0.46
38*	0	—	0.00	72.8	—
39	11	27.7	2.75		0.77
40	11	33.4	2.33		5.35
41	11	38.4	1.99		10.6
42	11	46.5	1.66		15.6
43	11	53.8	1.43		24.7
44	11	65.2	1.17		37.0
				Average—71.5	

* Pickup determination.

ducted through approximately 11⅓ passes of the tunnel.

In early drying experiments, considerable difficulty was experienced through sliver end breaks in the tower. The initial arrangement embodied polished steel rolls, and most end breaks were caused by fiber adherence to the top roll. Various clearing devices were tried without success, and the difficulty was finally eliminated by redesigning the tower rolls. The redesigned roll consisted of peripheral elements of glass rod or tubing approximately 6 millimeters in outside diameter, and ends of ½-inch thick rubber. The rubber ends were made from No. 10 stoppers, and were bored to receive the six tubing elements

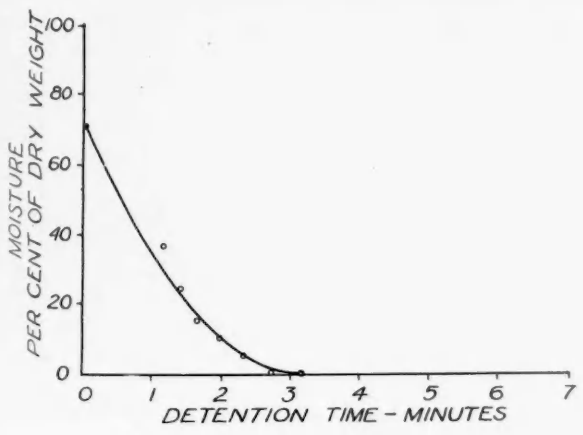

FIG. 3. *Results of drying test.*

TABLE II. EFFECT OF SLIVER SPEED ON YARN STRENGTH

Sample	Corrected skein strength of 11s yarns (lbs.)
1	232
2	234
3	236

on a circle of 1½-inch diameter. To complete the assembly, ends were then keyed to a cold-finished shaft by means of small steel pins. This arrangement was entirely satisfactory, and after the redesigned rolls were installed, end breaks due to rolls were negligible.

To repackage the treated sliver issuing from the drying section of the apparatus, one of a pair of 12-inch coiler heads from a discarded draw frame was used. Coiler heads, drying-tunnel top roll, and squeeze rolls were chain-driven by a ⅓-h.p. Master Speedranger motor, having infinitely variable countershaft speeds of 17 to 105 r.p.m. The existing sprocket arrangement provided a range of sliver speeds of from 12 to 65 feet per minute.

To maintain a constant level in the impregnation bath, a 5-pint reagent bottle filled with the treating solution was inverted in a steel tripod above the bath. A glass-tube connection between the bottle and the bath surface maintained the liquid level approximately constant.

The sliver impregnation apparatus as used in the experimental work herein described is illustrated in Figures 1 and 2.

Drying and Preliminary Spinning Tests

Before attempting any treatments, a number of preliminary tests were carried out to determine the drying characteristics of the apparatus. Since all tests were carried out in approximately the same manner, the results of only one study will be given as an example.

The lamp banks were set with the planes of the reflector edges 5½ inches apart, and sliver was wet out continuously in a bath containing 0.25 percent Aerosol OT in water, squeezed, and passed through the tunnel at various rates of speed. Moisture content of the wet sliver was determined by weighing a 15- to 20-gram sample of air-dry sliver to the nearest 0.01 gram, and passing it through the bath and squeeze rolls independent of the main sliver strand, care being taken to minimize the loss of fibers during

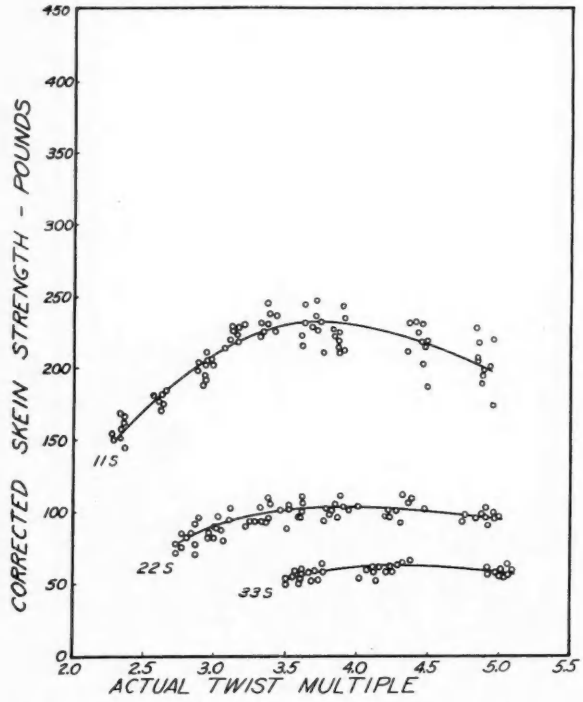

FIG. 4. *Effect of twist on strength of treated cotton. Cotton—$1\frac{1}{16}$-inch middling Bobshaw. Apparent add-on —0.47 percent.*

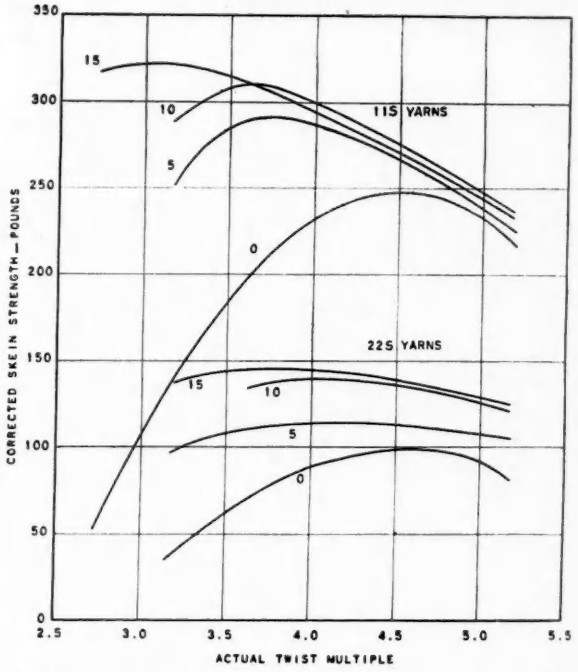

FIG. 5. *Effect of twist on skein strength of Bobshaw cotton treated with 0 to 15 percent Syton W-20.*

this treatment. The wet sliver issuing from the squeeze rolls was rolled into a tight ball by hand to cut down evaporation losses, and reweighed as rapidly as possible. Moisture contents of the dried samples issuing from the tunnel were determined by removal of an 8- to 12-inch length of the material to a tared weighing bottle, and subsequently drying at 105°C to constant weight.

Solution pickup and moisture content of the dried samples were expressed as a percentage of the bone-dry weight of the cotton (in the case of resin-treated samples on the resin-free basis).

The results of such a drying test are reported in Table I and appear graphically in Figure 3. It is apparent that under the experimental conditions the sliver reached its normal equlibrium moisture regain in approximately 2.2 minutes.

While the drying data are of doubtful reproducibility, owing to accumulation of dust on the external-type reflectors with time, and the deterioration of the lamps with age, the speed of operation in the resin treatments was held within a range which assured thorough drying.

To determine the influence of over-drying on the spinning qualities of the sliver, and also on yarn properties, a series of tests was run in which one sliver sample was subjected to rather severe over-drying for comparison with a sample dried at usual operating speeds and an untreated sample. Sample 1 indicated in Table II was untreated, sample 2 was wet and dried in the apparatus at 14.6 feet per minute and remained in the drying zone for 5.55 minutes, and sample 3 was wet and dried at a speed of 4.7 feet per minute, remaining in the drying zone for 17.2 minutes. All samples were then spun into 11s yarns at a twist multiple of 4.75 under identical conditions. Yarn-strength data for these samples appear in Table II.

Since the yarn strengths of all of the samples were essentially identical, it seemed safe to assume that even drying operations of unusually long duration do not influence yarn strength, when yarns are tested under single load applications.

Syton Treatments

Among the materials submitted for investigation in the sliver impregnation process was a colloidal dispersion of silica in water, Syton W-20.* It was

* This product and modifications which were used in later work were furnished through the courtesy of the Merrimac Division of the Monsanto Chemical Company.

pointed out that this product is an anti-slip agent, and was of some interest in the finishing of filament rayon fabrics and hosiery. Because of its frictional properties, and because the production of roughened fiber surfaces by such materials as rubber [11, 12], powdered glass or carborundum [13], inorganic salts [14], and organic salts [15] has been referred to in a number of patents, it seemed logical to include such a material in the investigations.

Although the application of anti-slip agents prior to the drafting operations would at first appear to present a serious obstacle in the production of yarns by normal spinning practices, minor modifications in the spinning technique, which will be discussed in a subsequent paper, permitted the production of yarns with little difficulty. The initial trials with Syton produced such marked changes in yarn properties that considerable attention was devoted to the treatment of cotton with this material.

The impregnation of sliver with Syton dispersions was carried out in the sliver impregnation apparatus previously described. Drying time in the tunnel varied from 2 to 4 minutes in most instances, and the treated sliver was conditioned for at least 24 hours in the spinning laboratory, which was maintained at 70°F and 65 percent relative humidity, before processing into yarn. The equipment used in spinning throughout this work was as follows:

Machine	*Process*
Drawing	Whitin Model H (1937)
Roving (single process)	Whitin Superdraft (1937)
Spinning	Whitin Model F-2 Long Draft (1937)

Solutions for the sliver treatment were prepared by dilution of the Syton W-20 to the desired concentration with water. A small quantity of Aerosol OT, 0.25 percent in most cases, was added as a wetting agent. All baths were analyzed for total solids, determined by drying of a bath sample to constant weight at 105°C. As an approximation of the quantity of bath solids deposited on the sliver, solution pickup of the sliver, expressed as percent by weight of the bone-dry, resin-free cotton, was multiplied by the bath-solids content, expressed as a weight fraction. This quantity, termed "apparent

TABLE III. SUMMARY OF SPINNING DATA

Yarn number	Syton W-20 in bath (%)	Apparent add-on (%)	Optimum twist multiple	Maximum skein strength (lbs.)	Strength increase (%)	Lowest twist multiple	
						Spinnable	For strength exceeding maximum of untreated cotton
11	0.0	0.25	4.1	245	—	2.2	—
	1.28	0.47	3.8	235	−4	2.4	—
	2.5	0.72	3.5	257	5	2.4	3.1
	3.8	1.02	3.6	255	4	2.2	2.9
	5.2	1.18	3.5	285	16	2.5	2.7
	7.7	1.78	3.2	303	24	2.4	2.4*
	10.2	2.06	3.1	310	26	2.4	2.4*
	15.0	3.30	2.7	323	28	2.4	2.4*
22	0.0	0.25	4.0	95	—	2.7	—
	1.28	0.47	3.9	105	10	3.0	3.3
	2.5	0.72	3.8	122	28	3.0	3.0*
	3.8	1.02	3.8	113	19	2.4	2.8
	5.2	1.18	3.6	115	21	2.7	2.7*
	7.7	1.78	3.5	130	37	2.7	2.7*
	10.2	2.06	3.6	138	45	3.0	3.0*
	15.0	3.30	3.3	147	55	2.7	2.7*
33	0.0	0.25	4.3	57	—	3.1	—
	1.28	0.47	4.2	65	12	3.2	3.8
	2.5	0.72	3.9	73	26	3.0	3.0*
	3.8	1.02	3.6*	71	22	3.6	3.6*
	5.2	1.18	3.7	72	24	3.1	3.1*
	7.7	1.78	3.3	85	46	2.9	2.9*
	10.2	2.06	3.1*	84	38	3.1	3.1*
	15.0	3.30	3.3	82	41	2.7	2.7*

* Lowest twist multiple spinnable.

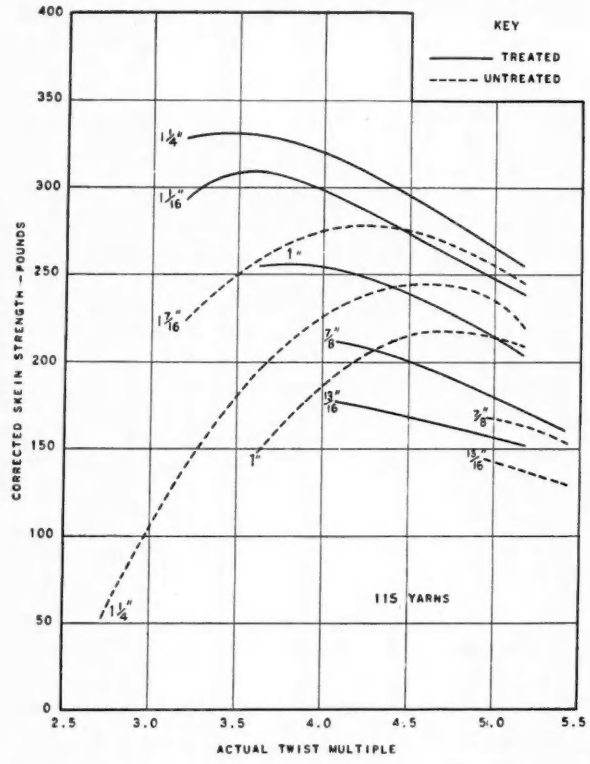

FIG. 6. *Effect of twist on skein strength of untreated and Syton-treated cottons of five different staple lengths.*

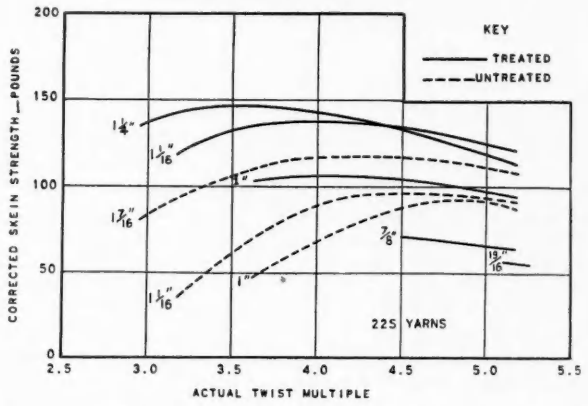

FIG. 7. *Effect of twist on skein strength of untreated and Syton-treated cottons of five different staple lengths.*

add-on," has the dimensions of percent by weight of the bone-dry resin-free cotton. It has been used in all resin treatments to express the approximate quantity of resin deposited on the fibers.

Interpretation of Yarn Data

Yarn strength was determined in skein form only, according to American Society for Testing Materials, Designation D180–44 [16]. The average strength of 10 skeins prescribed by this designation has been reported in all cases except when otherwise noted.

In most instances, yarn weights obtained in spinning deviate somewhat from the desired values owing to variations in roving weight and contraction during spinning. According to the A.S.T.M. skein test, the average yarn number is determined by weighing of the individual 120-yard skeins, and the strength reported is corrected from its actual value to the apparent value of the yarn number sought by direct proportion, according to the following expression:

$$S_2 = \frac{S_1 C_1}{C_2},$$

where S_1 is measured skein strength; S_2 is corrected skein strength; C_1 is actual yarn number; and C_2 is desired yarn number.

It was desired to present graphically the effect of twist on yarn strength in a number of instances, and after some consideration of the manner in which the data should be handled, it was decided to plot individual skein strengths versus "actual" twist multiple rather than the average value of 10 skein breaks, as determined by the A.S.T.M. test, versus the apparent twist multiple, which depends upon actual yarn weight for its true value.

In the fundamental expression for twist multiple,

$$TPI = T.M.\sqrt{C},$$

where TPI is turns per inch, $T.M.$ is twist multiple, and C is yarn number, the independent variables are apparently twist multiple and yarn number. In actual practice, however, turns per inch as determined by the twist gearing of the spinning frame at a given setting will remain constant regardless of the yarn weight produced. If, as is the case in practice, yarn number varies in an independent fashion, the twist multiple then becomes the dependent variable in the expression. It is therefore apparent that variations in yarn number produce variations in twist multiple along a yarn.

Another factor contributing to twist-multiple deviations was the fixed mechanical arrangement of the twist gearing of the spinning frame; it was not possible to realize the values of twist multiple—for example, 5.00, 4.50, 4.00, and the like, which were arbitrarily selected for use in the spinning tests. For instance, when it was desired to spin 11s yarn

at a 4.25 twist multiple, a 40-tooth twist gear and a twist constant of 553.2 gave a nominal twist multiple of 4.28, whereas a 39-tooth twist gear and the same twist constant gave a nominal twist multiple of 4.18. It was thus impossible to obtain a twist multiple of exactly 4.25 when producing 11s yarn on the spinning frame.

These discrepancies in twist multiple made it advisable to determine the actual twist multiple in order to permit greater precision in the plotting of corrected skein strengths. The actual twist multiples were determined from the relation:

$$T.M.\ (\text{actual}) = \frac{\text{twist constant}}{(N)(\sqrt{C_1})},$$

where N is number of teeth in twist gear and C_1 is true yarn number.

To eliminate confusion in the reporting of results, nominal twist multiples have been retained for use in the tables, although it is to be emphasized that actual values deviate slightly from these. In the graphical representation of spinning data, corrected skein strengths have been plotted against actual twist multiples.

Effect of Syton Concentration and Twist on Yarn Strength

Middling $1\frac{1}{16}$-inch Bobshaw cotton in card sliver form was impregnated in baths containing varying amounts of Syton W-20 and spun into yarn in counts of 11, 22, and 33. A condensation of the spinning-test results, obtained graphically from the original curves and showing the effect of twist multiple on skein strength, is given in Table III. Since the original spinning data were so voluminous, they have not been included, but a typical curve, Figure 4, has been included to indicate the method of correlation employed. Values of maximum skein strength given in Table III were obtained graphically from such curves as Figure 4.

A graphically obtained summary of the original curves on which Table III is based appears in Figure 5. Summary curves have been prepared for only 11s and 22s yarns, produced from cottons treated with concentrations of 5, 10, and 15 percent Syton W-20.

Table III and Figure 5 show clearly the shift downward in twist required for maximum skein strength in the treated cotton and the simultaneous

TABLE IV. OPTIMUM TWIST MULTIPLE AND MAXIMUM SKEIN STRENGTH FOR COTTON OF VARIOUS STAPLE LENGTHS

Variety	Upper-half mean staple length (Suter-Webb)	Untreated: Optimum twist multiple	Untreated: Maximum skein strength	Syton-Treated: Optimum twist multiple	Syton-Treated: Maximum skein strength	Syton-Treated: Percent strength increase	Syton-Treated: Lowest twist multiple giving same strength as untreated at optimum twist
11s Yarns							
$\frac{13}{16}$-in. West Texas	0.75	4.5*	145	3.7*	176	—	3.7*
$\frac{7}{8}$-in. Hi-Bred	0.87	4.6*	167	3.6*	212	—	3.6*
1-in. Rowden	1.01	4.3	216	3.3	255	18	3.1*
$1\frac{1}{16}$-in. Bobshaw	1.08	4.1	245	3.1	310	26	2.4*
$1\frac{1}{4}$-in. Acala	1.46	3.8	280	3.0	332	19	2.4*
22s Yarns							
$\frac{13}{16}$-in. West Texas	0.75	†	†	4.7*‡	55	—	—
$\frac{7}{8}$-in. Hi-Bred	0.87	†	†	4.5	51	—	—
1-in. Rowden	1.01	4.4	92	3.7	103	12	3.3*
$1\frac{1}{16}$-in. Bobshaw	1.08	4.0	95	3.6	138	45	3.0*
$1\frac{1}{4}$-in. Acala	1.46	3.9	118	3.1	148	25	2.5*
33s Yarns							
1-in. Rowden	1.01	4.6	53	3.8*	60	13	3.8*
$1\frac{1}{16}$-in. Bobshaw	1.08	4.3	57	3.1*	84	38	3.1*
$1\frac{1}{4}$-in. Acala	1.46	3.6	74	3.0	91	23	2.7*

* Lowest twist multiple which could be spun.
† Could not be spun.
‡ Highest twist multiple spun.

increase in maximum strength. In all cases the twist required for maximum skein strength in spinning Syton-treated cotton was lower than that required to develop maximum strength in the untreated cotton. It is apparent from the table that in one instance skein strength of the treated cotton was less than that of the untreated material. Whether this loss was due to decreased yarn uniformity, or to other causes, has not been determined. Observation of the yarn, and the results of a number of spinning tests, indicated that skein strengths of yarns from Syton-treated cotton were less uniform than those of comparable untreated cotton.

Effect of Syton on Various Cottons

In order to evaluate the effect of Syton W-20 on various varieties of cotton in different staple lengths, a series of four varieties in addition to the Bobshaw cotton used in previous tests were impregnated to contain as nearly 2 percent silica as possible, and complete spinning tests were made on both treated and untreated samples. The varieties used and the upper-half mean length as determined on the Suter-Webb sorter were:

Variety	Upper-half mean length (inches)	Grade
West Texas	0.75	Middling
Hi-Bred	0.87	Middling
Rowden	1.00	Middling
Bobshaw	1.08	Middling
New Mexico Acala	1.46	Middling

The optimum twist multiples and maximum strengths have been determined graphically and are reported in Table IV. Strength increases in treated cotton of from 11 to 45 percent have been realized. The summarized curves for yarn in numbers 11 and 22 appear in Figures 6 and 7.

Summary

The work described in the present paper covers the development of the continuous sliver impregnation apparatus and the effects of colloidal silica (Syton) treatments in the spinning operation.

The application of Syton to cotton in the form of sliver has been found to increase quite markedly the tensile strength of yarns spun from the treated cotton. In all cases investigated the skein strength of yarns from Syton-treated cotton produced at the lowest twist multiple spinnable exceeded the maximum strength of untreated cotton spun at its optimum twist multiple, of the same variety and staple length. Although some strength was realized in spinning treated cotton at conventional twists, the greatest strength increases were always obtained at twists lower than those required for maximum strength in untreated cotton. Visual inspection of the yarns from Syton-treated cotton indicated that they were somewhat less uniform than those of untreated cotton, and this lack of uniformity was reflected in less reproducible, although uniformly high, skein strengths.

Conclusions

From the spinning data and the curves obtained, the following conclusions have been drawn:

1. Syton-treated cotton of all staple lengths investigated can be spun at lower twists than untreated cotton of the same variety, staple, and grade.
2. The twist multiple for maximum strength is less in all cases for treated samples than for untreated samples.
3. The maximum strength of yarn spun from Syton-treated cotton sliver is in all cases greater than that of yarn spun from untreated cotton.
4. With a single exception, the tensile strength of yarn spun from Syton-treated cotton has been found to be greater than that of yarn of the same count and twist spun from untreated cotton of the same variety, staple, and grade.
5. In all cases investigated the skein strength of treated cotton at the lowest twist multiple spinnable exceeded the maximum strength of untreated cotton of the same variety and staple.
6. The high strength of Syton-treated cotton is maintained over a wide range of twist multiples below the optimum for untreated cotton.

Acknowledgment

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Book Reviews

Advances in Carbohydrate Chemistry. Volume I. Edited by W. W. Pigman and M. L. Wolfrom. New York, Academic Press, Inc., 1945. 386 pages. Price, $6.60.

(Reviewed by H. Mark)

The reviewer does not feel competent to appraise the value of a book on carbohydrate chemistry but, since all good carbohydrate chemists have contributed to this volume, the reviewing of it goes necessarily to people with only moderate knowledge of the subject.

The content of this first volume is indeed impressive. There is, first, an article by C. S. Hudson, the champion of sugar chemistry, on the "Cyanohydrins Synthesis and the Configuration of Higher-Carbon Sugars and Alcohols." It contains a very thorough treatment of this complicated topic, enumerates and describes a large number of rare sugars, and discusses their mutual structural relationships.

N. K. Richtmyer presents a chapter on the "Altrose Group of Carbohydrates," and discusses their relationship to other sugars, such as ribose, heptulose, etc. Two very valuable tables of D- and L-altrose and its derivatives, neolactose, celtrobiose, and their derivatives close this article.

The next chapter by Eugene Pacsu on "Carbohydrate Orthoesters" contains very interesting data on the preparation, characterization, and the theory of formation and hydrolysis of these interesting substances.

A. L. Raymond contributed an article on "Thio and Seleno Sugars," in which he discusses the structure and properties of natural thioglycosides and the synthesis, configuration, and reactions of synthetic thio and seleno carbohydrates.

A chapter on the "Carbohydrate Components of the Cardiac Glycosides" is presented by R. C. Elderfield, in which eight important substances of this class are enumerated; their chemistry and preparation are described in great detail and their biological importance is pointed out.

C. J. Carr and J. C. Krantz, Jr., contribute an article on the "Metabolism of Sugar Alcohols and Their Derivatives," from which they derive a number of important generalizations.

The important field of the "Chemistry of the Nucleic Acids" is treated by R. S. Tipson in a comprehensive and readable manner. The modern literature is critically reviewed and a number of interesting formulas for the structure of the phosphoric acid-ribose-pyrimidine complexes are given.

T. J. Schoch discusses the "Fractionation of Starch" and describes two newer methods—namely, fractionation by selective precipitation and by aqueous leaching. An interesting discussion of the properties and structures of the fractions and their significance for starch chemistry closes this chapter.

"Preparation and Properties of Starch Esters" is discussed in an interesting article by R. L. Whistler, who treats starch acetates very elaborately but describes a large number of other organic and inorganic esters of starch.

C. R. Fordyce treats in a comprehensive manner the "Organic Esters of Cellulose," giving, briefly, their industrial application.

The last chapter on "Plant Polyuronides" by E. Anderson and L. Sands, which contains a critical enumeration of the methods of testing of these materials, closes this volume.

The book is well organized; each chapter is clearly and concisely written; print and appearance are excellent.

Anyone who is ready to believe the reviewer, in spite of his ignorance of carbohydrate chemistry, can be assured that this is an excellent progress report on this interesting field of organic chemistry.

The New Fibers. Joseph V. Sherman, Herbert R. Simonds, and Signe L. Sherman. New York, D. Van Nostrand Company, Inc., 1946. 552 pages. Price, $5.00.

(Reviewed by Earl E. Berkley)

The expansion of industrial fabrics and increase in new household uses have encouraged the development and production of many types of manufactured fibers and stimulated the production of certain natural fibers that rarely appear on the market. In many instances the public has not been able to ob-

tain reliable information about the new fibers. This book is an excellent attempt to bring together the data, and it presents a good comparison in so far as possible. One is inclined to overlook the imperfections and repetitions appearing in the text and tables in his delight in finding so much new information.

The book gives the origin, physical properties, and use of the manufactured fibers and mentions some of the natural fibers, such as Typha. It also discusses the economic position of the man-made fibers. The numerous tables of physical properties repeat—perhaps legitimately—values given elsewhere in the text. For the most part references are given to the origin of the data presented, but occasionally conclusions that must have been drawn from physical-property data are given without reference.

For those interested in the patent literature, much time may be saved by using the list of patents given, which constitutes about one-third of the book. The numerous tables on physical constants, trade names, and comparative annual consumption of the various fibers will be of interest to the layman. The treatment of the natural fibers mentioned is not adequate but may encourage the interested reader to investigate them further.

This book shows some lack of polish; however, the corrections needed can be made readily in an early revised edition. All students of fibers will look forward to new additions to this valuable book as progress is made in manufactured fibers.

The Rayon and Synthetic Fiber Industry of Japan. H. Wickliffe Rose. New York, Textile Research Institute, Inc., 1946. Price, $6.00.

(Reviewed by Fessenden S. Blanchard)

Prior to the war, more than half of the industrial population of Japan was engaged in the textile industry. Japan's economic recovery now is to a great extent dependent upon the recovery of its textile industry. At the same time, American textile interests view with alarm the prospect of a revived Japanese industry capable of entering American markets and underselling our own mills, as Japanese bleached goods did in the late nineteen-thirties.

The importance of the Japanese textile industry in Japan's economy, its importance to the United States, both as an outlet for American cotton and as a potential competitor of American textiles, make especially valuable an authoritative work dealing with any part of this industry. With Japanese silk having permanently lost ground to rayon, nylon, and other synthetics, it seems probable that, as Japan gets on its feet again, great efforts will be made to revive and expand its rayon industry, which had become so important before the war. Before long, we may well find Japanese rayon staple fiber, yarn, and fabrics striving to enter the American market in a big way to replace the lost silk exports.

Hence, Wickliffe Rose's study, *The Rayon and Synthetic Industry of Japan,* is especially timely and valuable. This report is based on supplementary material gathered for the United States Department of State and War Department by a Textile Mission which spent January to March, 1946, in Japan. As a member of that Mission, Mr. Rose covered the rayon industry and trade and knows whereof he speaks.

The book covers in considerable detail the Japanese rayon industry as it was before the war and as it had become after the war at the time the report was written. It describes the rayon companies and their plants, their capacity, production, and the spindles for rayon staple. It tells of the Japanese use of blends, of the different raw materials in use, types of synthetic fibers and rayon yarn. It discusses leading Japanese associations interested in rayon, research and educational work, patents and tariffs. All of this is well indexed and backed up by references to the sources of information used.

This book should be in every textile library. It is a valuable source of information not only to all of those interested in the textile development of Japan but to those interested in the future of our own rayon industry, whether they are producers of rayon or users of its products.

Cotton in Plastic Laminates. Giles E. Hopkins. Washington, National Cotton Council of America, 1946. 28 pages. Free.

This report covers a survey conducted by the author for the purpose of determining the various factors influencing cotton's market in the laminating industry, with particular attention to the technical requirements governing the choice of fillers.

The importance of this market for cotton fiber and cotton fabrics is indicated by the statement that

"in 1947 the demand for cotton in laminates is expected to be between 50 and 64 million pounds. There is a potential demand for the characteristics of cotton filler which may amount to as much as 150 million pounds annually." On the other hand, the proportionate use of cotton filler appears to have shown a pronounced drop since the war, due to a number of influences among which are the relatively high price of cotton and the scarce supply.

The report describes the function of fillers and the factors controlling laminate quality, outlines the characteristics whereby cotton has an advantage over other fillers, and discusses the competition by other fillers, such as paper and glass fiber. It is pointed out that the active cooperation on the part of glass and paper engineers is helping to develop markets for their products which, once created, will likely result in the loss by cotton of important segments of the potential market for fillers.

The importance of yarn and cloth constructions is emphasized as well as the possibilities for the reduction of costs through development of special methods of assembling fibers. The development of a size which will eliminate the existing nuisance and might even result in a cost advantage is suggested.

A final chapter deals with the direction in which research may assist in widening the use of cotton in this field.

Callaway Textile Dictionary. W. L. Carmichael, George Linton, and Isaac Price. La Grange, Ga., Callaway Mills, 1947. 392 + vi pages. Price, $4.00.

In the compilation of a dictionary of over 6,000 words and terms used in connection with textile products and textile manufacturing, the authors and publishers of the *Callaway Textile Dictionary* have performed a service of great value to the industry.

Very few terms in common use have been overlooked. On the other hand, a large number of unusual terms are defined. The description is in each case concise but adequate and a number of illustrations are included.

The authors whose work is consolidated in this volume commenced separately several years ago the task of accumulating, defining, and organizing a listing of textile terms. Mr. Carmichael is a member of the faculty of the A. French Textile School of the Georgia School of Technology, Atlanta, Georgia; Dr. Linton is dean of the textile department, Fashion Institute of Technology and Design, New York City; and Mr. Price is on the staff of the Straubenmuller Textile High School, New York City.

The book is bound in a flexible cover of simulated black leather and the page size, $5\frac{1}{4} \times 7\frac{1}{2}$, is very convenient.

Sales Promotion in the Textile Industry. James C. Cumming. New York, Fairchild Publishing Co., 1946. 132 pages. Price, $3.00.

(Reviewed by Robert B. Evans)

Although the textile industry is the United States' second largest industry, it has been backward in promoting the sale of its products to consumers. There are indications that this situation is changing as a result of (1) the trend toward integration of textile firms, (2) the desire of textile firms to identify their product with the consumer and thereby protect their market, (3) the need to promote new synthetic fibers and finishes, and (4) passage of price control acts in various states which eliminate "footballing" of textile products by retailers. Promotion methods employed by rayon companies, textile mills, selling agents, and other groups in the industry are discussed in separate chapters. Actual firm names and case histories are used.

ABSTRACTS

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A list of periodicals, the abbreviations used in references to articles, and the addresses of publishers of English language publications is given on page 37 of the January, 1947, issue.

ANALYSIS: TESTING: LABORATORY METHODS

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Abrasion Testing

Recent advances in abrasion testing of textiles. F. Raymond Dean. *J. Text. Inst.* **37**, P380–91 (July 1946).

After indicating drawbacks in more elaborate methods of expressing the amount of abrasive treatment a fabric has been given, a visual end-point test is described in which this quantity is expressed in the more common way; that is, in a measure proportional to the time of exposure to a described action. A description is given of methods used for surmounting difficulties due to contamination which the abrasive may sustain as a result of rubbing the test specimens. Methods of test involving more objective measures of damage than visual estimation are described; data are given showing the deterioration in strength, bursting strength, and air resistance resulting from abrasion. In common with the visual test all these methods employ concentration of the abrasion on a small area of the sample for reasons which are stated. A yarn abrasion test is described and the use of yarn abrasion testing as a supplement to cloth abrasion testing is discussed in light of the data given. Methods used for harsh abrasion are briefly described. It is shown that reversals may arise in the order of ranking fabrics when the conditions of test, notably the type of abrasive, are altered and it is also shown that these may persist under controlled conditions in which they cannot be explained by contamination of the abrasive.

Author

Text. Research J. June 1947

Absorption and Emission of Radiation by Fabrics

Some observations upon the effect of color on the absorption and emission of radiation by a textile fabric. W. H. Rees, L. W. Ogden. *J. Text. Inst.* **37**, T113–20 (Apr. 1946).

Clothing for protection from solar radiation in the tropics deals with the absorption of these materials at relatively short wave lengths. Clothing in cold latitudes is for the reduction of heat loss from the body which deals with the emissivity of materials at relatively long wave lengths. The clothing materials tested were bleached and dyed cotton poplin of 3.06 oz./sq. yd. Fourteen various types of dyes were used. The absorptions of high temperature (arc-light source) and of medium temperature (electric-radiator source) were calculated from the initial rate of rise of temperature shown by kata thermometers, one uncovered and one covered with the material. The emissivity of a material sample is given by the ratio of galvanometer deflection with thermopile exposed to sample covering a black body to the galvanometer deflection with thermopile exposed to black body alone. The results show that the color of a fabric is a most important factor in determining the absorption of solar radiation but is of no importance in determining the emission at the long wave lengths associated with body temperature.

J. A. Woodruff

Text. Research J. June 1947

Fabric Test Standards

Are laboratory standards consumer standards? P. W. Webb. *Can. Text. J.* **63**, 37–40, 42–3, 54 (Nov. 29, 1946).

The present standards of evaluating textile products are criticized for lack of relationship to the cause of failure of products in use. Examples are given of failures in fabrics which are not accurately predicted by the use of laboratory testing machines. The standard of performance insisted upon by the manufacturer and the salesman is said to bear little relationship to the consumer's needs and often misleads through improper emphasis in labeling. A suggested research procedure in the establishment of standards is the evaluation of failures of products in use; the evaluation of accelerated field-test situations; the comparison of control and experimental textiles by the accelerated field test; the interpretation of laboratory results for the prediction of minimum constructions required to give the desired performance. J. A. Woodruff

Text. Research J. June 1947

Fabric Testing

Instruments test hand of fabrics. Anon. *Textile Industries* **111**, 66–7, 145 (Mar. 1947).

A brief discussion of the instruments available for evaluating various physical properties affecting the hand of fabrics. Mentioned are the Planoflex and the Pierce Hanging-Heart method for flexibility, the Drapeometer for hang, the Friction Meter for smoothness, and the Compressometer for thickness and resilience.

H. J. Burnham

Text. Research J. June 1947

Properties of Laminates

Impact strength and flexural properties of laminated plastics at high and low temperatures. J. J. Lamb, Isabelle Albrecht, and B. M. Axilrod. *Natl. Advisory Comm. Aeronautics, Tech. Note* No. **1054**, 30 pp. (1946) (through *Chem. Abstr.* **41**, 1875*b* (Mar. 20, 1947)).

The materials investigated were unsaturated polyester laminates reinforced with glass fabric (*I*), and phenolic laminates reinforced with asbestos fabric (*II*), high-strength paper (*III*), rayon fabric (*IV*), and cotton fabric (*V*). *V* was studied in both the high- and low-pressure types. The Izod-impact strength at 77°F was 4 to 7 ft.-lb. per in. of notch for *II*, *III*, and *V*; *I* and *IV* had strengths of 31 and 17 ft.-lb., respectively. Impact strength of *I* decreased to about 70% of its −70° value at 200°F; *II*, *III*, and *IV* showed little change with temperature. *V* approximately doubled in strength between −70° and 200°F. Outstanding flexural properties were shown by *I* and *III*, but on the basis of specific strengths, *III* and *IV* were superior to the others. Flexural properties increased for all materials at low temperature, and decreased at high temperature except for *II*, which showed no change at high temperature. It was emphasized that change in flexural properties at high temperature may be a function of humidity and further cure as well as temperature per se.

Text. Research J. June 1947

Electrical Measurement of Moisture Content

Determination of the moisture content in textile materials by measurement of the electrical resistance. H. Stierlein. *Textil-Rundschau* **1**, 164–9 (Dec. 1946).

Since the direct method for the determination of the moisture content of textile materials by conditioning cannot possibly keep up with the current continuous manufacture, indirect methods have been developed, which allow immediate reading of the moisture content. All these indirect methods measure a property of the textile material which is obviously dependent upon the water content. In the present case, the electrical resistance of fabrics is measured (Eiken apparatus); this has given excellent results with pure wool and cotton, but has frequently failed with artificial and mixed fibers. Numerous tests were carried out to determine when the moisture content of textiles can be safely measured by the electrical resistance and when it cannot. The test specimens were fabric discs of 100-cm² cross section and 1 mm. thick, with Cu-electrodes and direct current of 50 v. The procedure is described in detail. Examples of the dependence of the specific resistance upon the water content and pressure are illustrated by 1 table and 6 graphs, and show an increase in resistance with decreasing water content, passing from the completely wet to the air-dried state (about 14%), through 10^7. The difference in the water content of the surface and middle layers, which causes an enormous increase in the resistance of the drier layers, is a source of error. The electrical resistance depends also upon the condition of the water content, and is therefore subject to the temperature law of dilute solutions. It decreases about 2% per degree increase in temperature, so that measurements of freshly dried, still warm fibers differ from cold ones. The presence of salts as electrolytes increases the conductivity, thus also causing differences in resistance. The dependence upon pressure by application of variable loads at constant water contents showed that the resistances decrease much more than the fiber volumes increased. The materials tested were: fabrics—mixed 70% wool + 30% viscose, rayon; yarns of viscose staple fiber, acetylated viscose staple fiber, and acetylated viscose yarn. The tests showed that the determination of the moisture content with the Eiken apparatus depends too much on the personal factor of the operator (resulting in a different amount of twist). In the case of artificial fibers, especially fibers of viscose yarns, the plotting of one curve, which alone requires at least 10 hrs., is not sufficient. For accurate results it would be necessary to plot one curve for the staple fiber, one for yarns in skeins, and one for yarns on spools of each winding density, which is too expensive and time-consuming. Moreover, it is not definite whether or not the sensitivity of the instrument changes. Therefore the tried and tested conditioning, although bothersome, is still the best method. However, the Eiken-apparatus is recommended for checking plant

operations, where it is a question of one and the same fiber material; e.g., in testing the efficiency of a drier, or the moisture content of stored yarns to be introduced into operation. Ilse Zeise

Text. Research J. June 1947

Melamine and Phenolic Plastics

Creep, long time tensile and flexural fatigue properties of melamine, phenolic plastics. D. Telfair, C. H. Adams, H. W. Mohrman. *Modern Plastics* **24**, 151–2, 236, 238, 240, 242, 244, 246, 248 (May 1947).

Tensile creep data for cellulose- and asbestos-filled phenolic and melamine plastics indicate that they exhibit similar characteristics. The rate of elongation at 500 hrs. and the total elongation at 1,000 hrs. are of the same order of magnitude for each of the materials. The long-time tensile strength of the cellulose-filled melamine is superior to that of the wood flour-filled phenolic material. The melamine has a long-time tensile strength of about 67% of the short-time value as compared with approximately 36% for phenolic. Results of the repeated flexural stress tests indicate that the wood flour-filled phenolic plastic is slightly superior to the cellulose-filled melamine, the endurance limit for the phenolic being approximately 400 p.s.i. or 34% of the short-time static flexural strength, and for the melamine 3,000 p.s.i. or 31% of the short-time static flexural strength. Authors

Text. Research J. June 1947

Hydrolysis of Proteins

Cysteine losses resulting from acid hydrolysis of proteins. Murray Halwer and Geo. C. Nutting. *J. Biol. Chem.* **166**, 521–30 (1946) (through *Chem. Abstr.* **41**, 1724*a* (Mar. 20, 1947)).

The hydrolysis of 100-g. samples of various proteins to which 1, 2.5, and 5 mg. of cysteine were added resulted in recoveries of cysteine ranging from 32% to 81%, although cysteine, when subjected alone to the hydrolysis methods, could be recovered to the extent of 97.5% to 99.3%. Further study showed that part of the loss in cysteine may be due to reaction with reducing sugars present in some proteins. An unknown noncarbohydrate compound, however, seemed to be responsible for the loss of cysteine in the presence of lactoglobulin. The compound passes through a cellophane dialyzing membrane. Attempts to determine whether the lost cysteine was converted to cystine were inconclusive.

Text. Research J. June 1947

Identification of Stains on Rayon

The identification of stains on rayon yarns. G. Zuccari. *Tinctoria* **43**, 48–9 (1946) (through *Chem. Abstr.* **41**, 2249*g* (Apr. 10, 1947)).

For the identification of stains on rayon yarn the following tests are recommended: *Brown spots due to iron:* Dissolve in HCl and examine with KCNS or $K_4Fe(CN)_6$. *Other metallic stains:* Place the fiber in 5% logwood extract or a 0.03% solution of hematoxylin or hematein: Al gives a violet color, Cu grayish-blue, Pb ash-gray. *Yellowish-white stains of S:* Heat 10 g. rayon with 250 cc. 0.5% NaOH just to boiling, cool, and add a few drops of Na plumbite after 15 min. Also the test with Na nitroprusside can be used immediately after heating with NaOH. *Grease stains:* Absorb fat stains in filter paper, dissolve them in hot dilute NH_3 or the usual fat solvents; identify lubricating oils microscopically by translucence and fluorescence. *Graphite* remains as an insoluble incrustation. *Stains from Ca soap:* treat fiber with a freshly prepared solution of 5% gallic acid and NH_3. Ca changes the orange color of the solution into green. The milky appearance of the fiber, due to imperfect manufacture of viscose, the stains caused by too high a drying temperature, by Mn content of the bleaching solution, and by faulty dyeing are also discussed.

Text. Research J. June 1947

Detection of Surface-Active Agents

A qualitative method for detecting surface-active agents. L. F. Hoyt. *J. Am. Oil Chemists' Soc.* **24**, 54–6 (1947) (through *Chem. Abstr.* **41**, 2261*b* (Apr. 10, 1947)).

The reagent consists of a finely ground mixture of 2 parts Natl. Brilliant Oil Blue B.M.A. and 98 parts of NaCl. The sample is finely ground and 10 g. is digested with 50 ml. of hot 50% alcohol and filtered. The extract is evaporated to dryness and the residue digested with 3 ml. distilled H_2O and filtered into a test tube. Liquid or paste samples are first extracted with an organic solvent. Method: add 0.02 g. of the dry 2% dilution of Brilliant Oil Blue B.M.A. to the above aqueous extract. Shake and allow to stand for 1 hr. and compare with a blank. A concentration of 0.5 mg. of the organic component of surface-active agents in 2 ml. of H_2O will solubilize the Brilliant Oil Blue, producing a blue solution. The blank test will show a faint reddish-purple tinge, becoming clear and colorless after settling. The presence of 0.002% Nacconol NR.SF in a 10-g. sample can readily be determined. 13 references.

Text. Research J. June 1947

Identification of Surface-Active Agents

Ionic agents and their identification (active agents for the reduction of the surface tension). E. F. Göbel. *Rev. quím. ind.* **15**, 16–23 (340–7) (1946) (through *Chem. Abstr.* **41**, 2593*e* (Apr. 20, 1947)).

Methylene blue and uranin in equal quantities give in transmitted light the following colorations: with an anionic product, yellowish green to dark green with strong fluorescence; with a non-ionic product, navy blue with little fluorescence; with a cationic product, vivid blue to bluish red, with no fluorescence. In dilutions of 1:2000 to 1:5000 the coloration changes so that it can be utilized for better differentiation between the products of the group proper and the neighboring group. e.g., between acyl amides and alky-

laryl sulfonates, the former changing considerably toward blue, whereas the latter remain unchanged or change very little. This change between dilutions of the same product shows that there is a different behavior in the charge of the molecules, in reference to the surface tension and the molecular charges of the solution. Instead of $CaCl_2$ as used by Linsenmeier (*C.A.* **35**, 2635[6]) a 1% solution of crystalline $MgSO_4$ was used. $MgSO_4$ gave a clearer picture in the evaluation of the alkylaryl sulfonates, oils and esters of sulfonated oil, and fatty alcohols. Wetting tests, cleansing and degreasing tests, emulsion tests, dye-fixation tests, and tests of power of dispersion are recorded. 11 references.

Text. Research J. June 1947

Viscosity of Liquids

Measurement of the viscosity and shear elasticity of liquids by means of a torsionally vibrating crystal. W. P. Mason. *Trans. Am. Soc. Mech. Eng.* **69**, 359–70 (May 1947).

This paper describes a method of measuring viscosities of liquids at high frequencies by means of oscillating cylinders, in which a torsionally vibrating crystal generates a viscous wave in the medium to be measured. Both a reactance and a resistance loading occur in the crystal which lowers its frequency and raises the measured resistance at resonance. The viscosity may then be determined by measuring the changes in the properties of the crystal. By varying the voltage on the crystal, the shearing displacement can be varied and hence the viscosity can be measured as a function of shearing stress. Measurements on light oils over a viscosity range from 0.01 poise to 10 poises check within a few percent when made with rough temperature-control conditions. Author

Text. Research J. June 1947

Determination of Wool

Method of determination of wool in mixtures with cotton. A. Della Giovanna and E. Cerbaro. *Tinctoria* **43**, 196–8, 235–7 (1946) (through *Chem. Abstr.* **41**, 2250*d* (Apr. 10, 1947)).

The indirect methods of determining wool in cotton mixtures by dissolving it either in acetic and nitric acids or in 2.5–10% NaOH are not very accurate, as even pure cotton loses about 5% in weight by these treatments. The direct determinations by treatment with H_2SO_4 58°Bé. for 2 hrs. (*I*) (*cf.* Villavecchia, *et al.*, *Trattato de chimica analitica applicata* **II**, p. 1010 (*C.A.* **31**, 5722[7])), with H_2SO_4 59.5°Bé. (*II*) (*cf.* Heermann, *Färberei-und Textilchemische Untersuchungen*, p. 267 (*C.A.* **35**, 2002[6])), with boiling 1% H_2SO_4 for 7–10 min. and with H_2SO_4 55°Bé. for 15 min. at 38° (*III*) (A.S.T.M. tentative standard D276-37T), or by boiling with $AlCl_3$ solution (*IV*) (*ibid.*) are tested in their action on pure wool. Virgin wool and processed or reconditioned wool, respectively, showed on the average the following changes in weight: *I:* +2.9% and −3.5%; *II:* +3.9% for virgin wool; *III:* +0.8 and −2.5%; *IV:* −0.6 and −4.0%. The increases in weight are due to combination of H_2SO_4 with the wool. *III* is recommended as the most reliable method.

Text. Research J. June 1947

Swiss Test Methods

Raw materials and products of the textile industry. C. yarns and threads. SVMT 25 C 1011 Prestretching. *Textil-Rundschau* **2**, 23–4 (Jan. 1947).

The tensioning to be applied prior to the different measurements carried out on yarns and threads is defined. The loads to be used can be read from a log-log plot of denier against the tensioning in g. **SVMT 25 C 1012 Length measurements on yarns and threads.** *Idem.* The determination of the number or denier, of the uniformity within a number, and for the measurement of the running lengths of yarn skeins, spools, etc., is described. **SVMT 25 C 1031 Determination of yarn numbers.** *Ibid.* 61–4. The term "number" is defined and its determination by the conventional method—i.e., after conditioning the samples at 20°C and 65% R.H. for 24 or 72 hrs.—is described.

Text. Research J. June 1947 Ilse Zeise

CHEMICAL AND PHYSICAL RESEARCH

★

Absorption of Acetone by Cellulose

The constitution of gels of nitrocellulose and acetone. Édouard Calvet. *Ann. faculté sci. Marseille* **16**, 17–35 (1942) (through *Chem. Abstr.* **41**, 2303*b* (Apr. 20, 1947)).

A previous paper (*C.A.* **38**, 3888[3]) is amplified. Acetone absorbed by nitrocellulose is not fixed on the NO_2 groups as claimed by Kargin and Papkov (*C.A.* **31**, 1287[5]). Ordinary cellulose in the form of absorbent cotton (or cotton for nitration) will absorb acetone. The heat evolved per g. of acetone is about 80 cal./g., as with nitrocellulose. The vapor tensions of gels of nitrocellulose and acetone were measured at 16.3°. Activities were plotted against molecular concentrations of acetone in nitrocellulose in comparison with similar data obtained at 40° by Desmaroux and Mathieu (*C.A.* **30**, 2367[8]); cf. also Desmaroux (*C.A.* **28**, 5659[8]). 14 references.

Text. Research J. June 1947

X-Ray Diagrams of Cellulose

The diffusely diffracted radiation in the x-ray diagrams of cellulose fibers. P. H. Hermans and A. Weidinger. *Rec. trav. chim.* **65**, 620–3 (1946) (in English); cf. *C.A.* **40**, 4514[7] (through *Chem. Abstr.* **41**, 2239*d* (Apr. 10, 1947)).

The details of a technique are given for characterizing the x-ray spectrum of the amorphous portion of cellulose from the general diffuse background scattering. Exposure is made in an Asbury comparison camera. The diffracted radiation is intercepted in 2 quadrants by a Pb sector placed over the film. Every 10 min. the fiber (prepared from viscose) is removed and the sector

rotated 90°, thus exposing 2 film quadrants to the radiation scattered by air and the diaphragm only. Two films separated by an Al sheet 0.3 mm. thick are used. This permits transmission of the entire hard, white radiation and absorbs practically all of the Cu *K*-radiation. Thus, one film is exposed in 2 quadrants to the radiation diffracted by cellulose, air, and diaphragm and the other film (in the other quadrants) to radiation diffracted by air and the diaphragm only. The spectrum consists of a very broad band having a flat maximum between the 101 and the 10$\bar{1}$ interference corresponding to a spacing of 5–6 Å.

Text. Research J. June 1947

Foamed Cellulose Acetate

Foamed cellulose acetate—a new plastic. R. A. Hoffer. *Materials and Methods* **25**, 58–61 (1947); cf. *C.A.* **40**, 4913[4] (through *Chem. Abstr.* **41**, 2270*i* (Apr. 10, 1947)).

The plastic is cellulose acetate in an unorientated multicellular form, is lighter than cork, and can be used to bond together wood and metal. Applications are described and illustrated.

Text. Research J. June 1947

Protective Colloids

Protective Colloids. F. Enderlin and L. Schibler. *Textil-Rundschau* **2**, 3–11 (Jan. 1947).

Nineteen different samples of a new class of organic substances of medium-high molecular weight which are used as textile agents are compared with 9 samples of well-known colloids, such as gelatin, casein, etc., with respect to their protective colloid properties by the determination of the "gold number" of Zsigmondy and the "ruby number" of Ostwald. The preparation of the necessary reagents, the determinations themselves, and the results are described in detail. Based on the gold numbers obtained, the substances were classified in accordance with the suggestion of Zsigmondy by division into 4 different efficiency classes. The leveling and penetrating agent, Albatex PO (a fatty-acid condensation product), shows practically the same protective action toward a colloidal gold solution as a technical gelatin of excellent quality would show. The results of the determination of the ruby number of Ostwald agreed well with those of the gold number, and, as with the gold-number classification, the substances were classified according to their Ostwald ruby number. Substances which with 4 cc. of a 10% solution are incapable of giving protection against a Congo ruby solution were given the ruby number ∞ or a protective action = 0. Albatex PO occupies a special position also in its behavior toward Congo ruby solution. It has an extremely high protective power, which is exceeded neither by the well-known protective colloids, gelatin and casein, nor by the effective high-molecular polyether-alcohols. Tables give the gold and ruby numbers and the Zsigmondy class of the colloids investigated. Ilse Zeise

Text. Research J. June 1947

Emulsification, Foaming, and Wetting

The role of the surface layer in the phenomena of emulsification, foaming, and wetting. II. Molecular structure and role of emulsifying agents. F. Lachampt and D. Dervichian. *Bull. soc. chim.* **1946**, 491–4 (through *Chem. Abstr.* **41**, 2260*h* (Apr. 10, 1947)).

A general discussion of emulsions and emulsifying agents. **III. Structure and role of foaming agents.** *Ibid.* 495–7. A discussion of foams and compounds used to promote and to inhibit foam formation.

Text. Research J. June 1947

The effect of surface layers on wettability and foaming of emulsions. D. Dervichian and F. Lachampt. *Bull. soc. chim.* **1946**, 486–91 (through *Chem. Abstr.* **41**, 2260*i* (Apr. 10, 1947)).

A general discussion on emulsions in which a mechanism involving a surface layer is used to explain wettability and foaming.

Text. Research J. June 1947

Evaporation of Liquids

Evaporation of liquid from a free surface. G. N. Hoodyakov. *Bull. acad. sci. U.S.S.R., Classe sci. tech.* **1946**, 533–41 (through *Chem. Abstr.* **41**, 2292*g* (Apr. 20, 1947)).

The heat from a radiant heater is transmitted to the free surface of a liquid by radiation only. The relation between the velocity of the evaporation and the temperature of the free surface of the liquor can be expressed by the equation $Q = G[r + C(t_1 - t_0)]$ cal./sq. m./hr. Q = heat absorbed by the surface of liquor from a body fixed above the free surface of the liquor; G = liquor evaporated in kg./sq. m./hr.; r = latent heat of evaporation; C = average specific heat of the liquor; t_1 = temperature on the surface of liquor; t_0 = temperature of the liquor before the beginning of the experiment. $G = K(P_s/p)$ kg./sq. m./hr., where P_s = pressure of saturated vapor at the temperature of evaporating liquor in mm. Hg; p = atmospheric pressure in mm. Hg; K = constant, depending on the nature of the liquor. It was found to be for distilled H_2O 25, C_6H_6 47, iso-BuOH 54, and C_6H_5Me 116. For the same temperature of the surface of the heater the heat transmitted by radiation from above and absorbed by the same size free surface differs for different liquors; this fact indicates differences in the coefficient of the thermal radiation.

Text. Research J. June 1947

Filament Size and Fabric Properties

Yarns for special purposes—Effect of filament size. D. Finlayson. *J. Text. Inst.* **37**, P168–80 (July 1946).

A formula frequently used for the calculation of fiber denier from width measurements is: $d = w^2s/141.5$, where d is denier, w is fiber width in microns, and s is density in g./cc. This is based upon the admittedly incorrect assumption of circular cross section. The formula gives accurate results only for glass fibers. A new formula is

proposed, $d = 3w^2/400$, which is equivalent to an assumption of circular cross section and a density of 1.06. It is based on a rough correlation existing between density and irregularity of cross section. It is claimed to give results with wool, silk, acetate, nylon, viscose, and natural cellulosic fibers of sufficient accuracy for practical purposes. Width measurements and calculated deniers are given for 38 natural fibers. The range of fiber widths is also given. The most important fiber property that is affected by denier is fiber flexibility. If a fiber is supported at one end as a cantilever, and deflected by a load, it is shown that the following equation holds: $f/Fl^3 = k\ R\ s^2/E\ d^2$, where f is the deflection, F the load, l the length, R the ratio of major to minor fiber diameter, s the density, E the modulus of elasticity, d the denier, and k a constant. The term F/Fl^3 is defined as the intrinsic filament flexibility. The deniers of various synthetic fibers at which the flexibility is equal to that of natural silk is calculated by means of the expression $D = ks\sqrt{R/E}$ derived from the above equation. These are: silk 0.97, acetate 1.47, viscose 0.96, nylon 1.11, Fortisan 0.63, and glass 0.44. Practical applications of these principles are described. A. R. Martin

Text. Research J. June 1947

Jute

Action of light upon jute. H. J. Callow. *Nature* **159**, 309 (Mar. 1947).

A study of the chemical reactions which take place on irradiation of jute. The formation of relatively low-molecular-weight products derived mainly from the ligneous encrusting materials, and possibly from the hemicellulosic constituents, is reported. The author suggests the source of the colored derivatives produced by irradiation is demethoxylation of the lignin-forming units to polyhydroxy phenolic fission products which are converted to quininoid forms, and the formation of furfural polymers or furfural-phenol condensation compounds. Acetylation in aiding color inhibition appears to prevent quinone formation and also to cause production of a bleaching agent. R. W. Eyler

Text. Research J. June 1947

Keratin

Structure of the keratin molecule. J. B. Speakman. *Nature* **159**, 338 (Mar. 1947).

The alpha-beta transformation was investigated by studying the extension of wool fibers under constant stress in saturated air at low temperatures. It is shown from extension of the fibers with time that the extension over the period of 1 to 13 days is due to slow unfolding of the molecules of alpha-keratin in the crystalline phase. The activation energy associated with the alpha-beta transformation was calculated and agrees with Astbury's conception of the nature of the intramolecular fold in alpha-keratin.

Text. Research J. June 1947 R. W. Eyler

Microscopic Mounting Media

The piccolyte resins as microscopic mounting media. L. F. Wicks, C. Carruthers, and M. G. Ritchey. *Stain Tech.* **21**, 121–6 (1946) (through *Chem. Abstr.* **41**, 2269*f* (Apr. 10, 1947)).

A new series of synthetic resins, the "piccolytes" (β-pinene polymers), is recommended for permanent mounting media in histological work. A partial review of the literature on synthetic-resin mountants is included.

Text. Research J. June 1947

Mechanism of Oxidation

Recent advances in science: Physical chemistry. J. W. Smith. *Science Progress* **35**, 108–20 (1947) (through *Chem. Abstr.* **41**, 1917*f* (Apr. 10, 1947)).

A review of recent researches on the mechanism of oxidation and reduction reactions involving electron transfer.

Text. Research J. June 1947

Structure of Starch

Structure of starch and cellulose. T. G. Halsall, E. L. Hirst, and J. K. N. Jones. *Nature* **159**, 97 (Jan. 1947).

Conclusions drawn from data from end-group determinations on starches are presented. The authors present conclusions at variance with the structure of starch suggested by Pascu and Hiller.

Text. Research J. June 1947 R. W. Eyler

Naphthalene Sulfonic Acids

A theoretical discussion of positional sulfonation of naphthalene and of some of its derivatives. Part 1—Naphthalene and its sulfonic acids. H. H. Hodgson and D. E. Hathway. *J. Soc. Dyers and Colourists* **63**, 46–8 (Feb. 1947).

An interpretation of the experimental data on the sulfonation of naphthalene is submitted which is based on the modern resonance theory. Analogies throughout are made to the corresponding data on the nitration of naphthalene, since both sulfonating and nitrating agents are electrophilic. Sulfonation is always believed to occur in the α-positions initially, but resonance structures are used to explain the simultaneous β-sulfonation which also takes place. Temperature conditions determine the preferential hydrolysis of α-sulfonic groups, which are structurally less firmly united to the naphthalene nucleus owing to the greater strain in the $C{=}SO_3H$ bonds, so that sulfonation must then occur in β-position, although examples of resulfonation in α-position are cited. Further sulfonation of the α- and β-naphthalene sulfonic acids thus involves the above isomerizations, and at high temperatures the 2:7-disulfonic acid is the main product of disulfonation, with the 2:6-acid in smaller amount; trisulfonation can give a mixture of 1:3:5-, 1:3:6-, and 1:3:7-acids, whereas the other two pass into the 1:3:5:7-tetrasulfonic acid on further sulfonation. All the various changes can be explained by the predominance of relevant structures in the resonance hybrid. Authors

Text. Research J. June 1947

BLEACHING: DYEING: FINISHING

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Direct Dyes

The dyeing properties of direct colours. G. G. Bradshaw. *Dyer* **57**, 255–9 (Mar. 14, 1947); 323, 325 (Mar. 28, 1947).

Factors to be considered in direct dyeing are listed as "strike," rate of dyeing, time of half-dyeing, salt, and temperature. The absorption of the dyestuff at the surface of the fiber is called the "strike." A discussion is given of the above dyeing factors followed by a further discussion of the practical value of the data obtained from studying these properties. J. A. Woodruff

Text. Research J. June 1947

Dyestuffs from Waste Products

Industrial utilization of sawdust and fiber-tows in the preparation of a dyestuff. Bibhutybhusan Biswas and Dattaraya Yashwant Athawale. *J. & Proc. Inst. Chem.* (India) **17**, 103–10 (1945) (through *Chem. Abstr.* **41**, 2245*i* (Apr. 10, 1947)).

Preparation of S dyes from sugar-factory press (Nagraja Rao and Jain, *C.A.* **35**, 5737[1]) and from carbolic acid manufacture wastes (Vasserman *et al.*, *C.A.* **27**, 5543) has been carried out, but the thionation of fiber-tow, sawdust, and similar substances containing no aromatic nuclei is new. Cellulosic manufacture waste, e.g. starch, glucose, cellulose, or lignin, 10 g., is mixed in an Fe crucible with 10 g. S and 4 g. NaOH, transferred to a fire-clay crucible, covered with an asbestos pad, and heated at dull red heat until the reaction is complete. Careful heating and proper amounts of reagents are essential. A sun-, soap-, and soda-resistant and very insoluble drab brown dye results. Mucic acid may be used, but urea, succinic acid, and beeswax products have no tinctorial value. Costs, materials, and yields of dyes for large-scale production are given.

Text. Research J. June 1947

Identification of Dyes

Identification of dyes on wool and silk. Obtained from Director Leonard, École Supérieure des Textiles de Verviers (Belgium). *Textilteknik* **4**, 185–92 (Dec. 1946).

A series of chemical tests which make it possible to identify a dye in the dyed fabric—i.e., to determine to which group a dye used for dyeing wool or silk belongs—consists of (1) investigation of the mordant used and (2) extraction, reduction, and reoxidation tests of the dyes. For (1) a sample of 5 g. is cut into small pieces, ashed with alkali, and heated toward the end over a blast lamp until the ash is homogeneous and free from unburned C. The color of the ash gives important information. A white ash indicates the presence of Al or Sn; a grayish-green, Cr; a brown, Fe; and a black, Cu. The ash is then fused with 5 times its weight in $NaKCO_3$ and a small addition of KNO_3. If the fiber has been mordanted with Cr, the melt is yellow, the Cr being identified with acetic acid and lead acetate; if with Fe, the melt dissolved in HCl gives on addition of KCNS a blood-red coloration; with Cu, the melt dissolved in HNO_3 gives a blue coloration with aqueous NH_3; if the mordant contained Al or Sn, the melt is treated with aqua regia, evaporated to dryness, the residue dissolved in HCl and the Sn determined by introduction of H_2S, and the Al with aqueous NH_3. For (2) the following reagents are required: (*a*) 5% solution of acetic acid; (*b*) 1% NH_4OH solution; (*c*) 1.1 solution of alcohol and water; (*d*) 1:10 solution of concentrated HCl and water; (*e*) a cold-saturated aqueous solution of $K_2S_2O_3$ or a 2% solution of $(NH_4)_2S_2O_8$; (*f*) a 5% solution of Na_2CO_3; (*g*) a solution of 10 g. Rongalit C in 100 cc. of water. 7 schemes for the identification of the dyes are established according to color. They are: (*I*) yellow and orange dyes; (*II*) red dyes; (*III*) purple-red and violet dyes; (*IV*) blue dyes; (*V*) green dyes; (*VI*) brown dyes; (*VII*) black and gray dyes. All dyes are extracted from a textile sample (surface 2–3 cm^2) in an ordinary test tube with (*a*) and then subjected to treatment with the other reagents, depending upon the amount of color they have yielded. The tables show the different treatments and color changes for the corresponding dye groups. New textile samples must be used for each test with the exception of the reoxidation test. Cotton pieces are boiled with the samples, the coloration of which helps in the identification. The reduction test by boiling with Rongalit C allows a first classification into (*A*) dyes that are decolorized with Rongalit C, which is subdivided again into those which will return to their original color in the open—azine-oxazine-thiazine group, indigo; those whose color will return with the use of persulfate—triphenyl-methane groups; and those whose decolorization is final—nitro, nitroso, and azo groups; (*B*) dyes which remain unchanged—pyrone, acridine, quinoline, thiazole groups, and some anthracene dyes; (*C*) dyes which are not decolorized but whose tones change. The color returns in the open or with persulfate in the case of anthracene dyes and indigos. The classification is then continued in the 7 schemes. The test procedure is described in detail and helpful hints given for correct identification. Ilse Zeise

Text. Research J. June 1947

Hosiery Dyeing

Ladies' hose—Dyeing and finishing processes. Part I. A. J. Hall. *Fibres* **2**, 60–3 (Feb. 1947).

A detailed review is given of the preparation of ladies' hose for dyeing. Descriptions are given of hosiery dyeing machines.

Text. Research J. June 1947

Effect of Fiber Swelling on Dyeing

The relation of fiber swelling to dyeing behavior of viscose staple rayon. Stephan Jost. *Textil-Rundschau* **1**, 67–75 (1946) (through *Chem. Abstr.* **41**, 2249*d* (Apr. 10, 1947)).

Rayons with varying degrees of swelling, measured in H_2O and 10%

NaOH solution, were obtained by molecular degradation through oxidation and acid hydrolysis and by selection of different types of commercial rayons. The dyeing conditions were: bath concentration 0.05 g. Chicago Blue 6B and 5 g. NaCl per l., bath volume 1:5000, temperature 70°, time 10 or 180 min. The amount of dye taken up by the rayon was determined by extraction. The total amount of dye taken up was greatly reduced through oxidation by Cl in alkaline solution but was practically unchanged by Cl in neutral solution or by acid hydrolysis. The rate of dyeing is essentially unchanged by any of these treatments. In rayons of similar degree of polymerization, but differing with respect to (1) hollow *vs.* solid fibers, (2) spinning stretch, (3) fiber denier, a greater swelling and a more rapid rate of dyeing were correlated, but the amount of dye taken up after balance had been reached was nearly independent of the swelling conditions. 3 tables, 38 references.

Text. Research J. June 1947

Textile Printing

Spotty and measly effects in textile printing. Anon. *Can. Text. J.* **63**, 37–40 (Dec. 27, 1946).

A practical discussion is given of printing faults originating in cloth structure, badly engraved rollers, faulty print pastes, poor printing foundations, and faulty size removal. Methods of mitigating these bad effects are offered.

J. A. Woodruff

Text. Research J. June 1947

Developments in Finishing

Chemical developments in textile finishing. L. R. Sheps. *Can. Text. J.* **63**, 40–2 (Nov. 1, 1946).

Descriptions are given of the properties and uses of anionic, cationic, nonionic, and synthetic polymeric chemicals in textile finishing. The application of the polymeric chemicals is discussed under the headings: surface coating, discontinuous surface impregnation, and intrafiber deposition. 25 references.

J. A. Woodruff

Text. Research J. June 1947

Mothproofing and Showerproofing

Mothproofing and showerproofing. M. Kolker. *Dyer* **57**, 295–7 (Mar. 28, 1947).

A review of the methods of preserving wool from damage by moth larvae is given. Methods of obtaining and testing showerproofing on wool is also discussed.

J. A. Woodruff

Text. Research J. June 1947

Freney-Lipson Shrinkproofing Process

Further studies of the industrial development of the Freney-Lipson process. J. L. Clay. *J. Council Sci. Ind. Research* (Melbourne) **19**, 256–68 (1946); cf. *C.A.* **37**, 6135[2] (through *Chem. Abstr.* **41**, 2582*h* (Apr. 20, 1947)).

Treatment of knitted woolen garments by the Freney-Lipson shrinkproofing process was studied. A nonfelting finish on wool is produced by immersion for 10 min. at 80°F in the Freney-Lipson reagent (*I*) prepared by dissolving 10 lb. of KOH in 1 imperial gal. of H_2O and adding this solution to 40 gal. of absolute alcohol containing 3.2 lb. of glycerol. The residual KOH on the wool is neutralized with a solution containing 4 lb. concentrated H_2SO_4 in 40 gal. of water, and, after a water rinse, the residual acid is neutralized with a solution containing 11 lb. Na_2CO_3 and 9 lb. $NaHCO_3$ in 100 gal. of water. After another water rinse the handle of the treated wool is restored to normal in a solution containing 8 oz. of a cationic softening agent in 100 gal. of water. Factors affecting the efficiency of the process were studied by making determinations of felting shrinkage and extensibility. The conditions of treatment may be varied considerably without reduced efficiency or damage to the wool, but the concentration of water and the temperature of *I* should not exceed 5% and 86°F, respectively. *I* has an almost unlimited life providing the woolen material is dried before treatment to a regain of approximately 5%. The neutralizing acid must be renewed after treating approximately 10 batches to prevent staining. Materials treated in the pilot plant had good felting resistance, handle and color, and dyed and mixture fabrics were not adversely affected. White fabrics were discolored when treated with the same solutions as dyed fabrics because of slight bleeding of the dyes. The costs of operating the process are assessed.

Text. Research J. June 1947

FIBERS: YARNS: FABRICS MECHANICAL PROCESSES

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Acrylonitriles

A new class of synthetic fibers. Joseph V. Sherman. *Textile World* **97**, 101–2, 215–16 (Mar. 1947).

A general discussion of the properties of the 2 new fibers based upon acrylonitrile. These are Vinyon N, a copolymer of acrylonitrile and vinyl chloride, and Fiber A, which contains not less than 85% polyacrylonitrile. A bibliography of 25 patent references covering these polymers is given. H. J. Burnham

Text. Research J. June 1947

Wet Strength of Fibers

The relations between the structure and properties of textile fibers. III. The relative wet strength of the textile fibers. Germano Centola. *Ann. chim. applicata* **36**, 82–8 (1946); cf. *C.A.* **40**, 3268[2] (through *Chem. Abstr.* **41**, 2247*h* (Apr. 10, 1947)).

The different relative strengths in the wet state between natural and artificial fibers was attributed by Lauer (*C.A.* **38**, 1355[3]) to the supposed hydrophobe nature of the crystallized portion of the fiber in natural fibers and hydrophile nature in artificial fibers. Experiments of Centola made on cotton, ramie, flax (raw materials, or bleached with various methods), and viscose rayon do not agree with this supposition. Probably the macro-molecules which form the micellar "fringes" uniting the crystallized zones of the fibers, when free

from the incrustant matters, become more easily accessible to water, and are broken nearly simultaneously when the fibers are extended.

Text. Research J. June 1947

Flax Fiber Preparation

The processing of domestic flax for textile use. J. L. Taylor. Atlanta, Ga., Georgia School of Technology, State Engineering Experiment Station, 1946. **I. Decortication** (Bulletin No. 9, 28 pp.). **II. Retting and Degumming** (Bulletin No. 10, 24 pp.). Price per bulletin, 75 cents.

Experiments indicated (Bulletin 9) that the best system of machines to produce shive-free decorticated flax fibers consists of (1) a stapling machine, (2) retting tanks, (3) a tunnel drier, (4) a decorticator, (5) a dusting machine, and (6) a fiber condenser. Quality of the fiber produced was not sufficiently high to permit economical spinning of all-flax yarns on cotton machinery but was highly satisfactory in blends with cotton and other fibers. A liquor-circulating type of digester (kier) was found most satisfactory for degumming fiber (Bulletin 10) and fiber thus processed was believed to be satisfactory for cotton-system spinning. R. B. Evans

Text. Research J. June 1947

Thread and Cordage Manufacture

Modern thread and cordage manufacture. The wet-spinning process. Anon. *Fibres* **2**, 50–3 (Feb. 1947).

A discussion of the merits of dew-retted and water-retted flax is given. The mechanical operations of spinning practice are described. 2 diagrams. J. A. Woodruff

Text. Research J. June 1947

Worsted Yarn Defects

Improving worsted yarn quality. Anon. *Can. Text. J.* **63**, 43–4 (Nov. 15, 1946).

A review of causes of defects in yarns occurring in operations from re-combing to spinning and advice on the elimination of same.

Text. Research J. June 1947

Card Clothing

Installation technique improved for metallic clothing. C. R. Pease. *Textile World* **97**, 118–20 (Mar. 1947).

Practical instructions for mounting metallic card clothing on cylinders and doffers.

Text. Research J. June 1947

New Spinning Machine

Spinning-machine drafts without rolls. C. W. Bendigo. *Textile World* **97**, 113, 188 (Mar. 1947).

Description of a machine in which roving is drafted and spun into yarn without drafting rolls. Two sets of intermittently operating dogs grasp the fibers and draft the roving the desired amount, with the bottom dog moving more than the top dog to accomplish the drafting. The fibers are combed between the dogs as they are pulled out. Twist from the spindle runs up to a set of clamps placed between the sets of dogs. It is said that extremely short fibers can be drafted by this machine. This new method of drafting and combing during the spinning operation has other inherent advantages: (1) drafting is started slowly; therefore fibers are not suddenly pulled through their surrounding fibers, as is the case when roll drafting is used; (2) in combing, there are no noils removed; (3) draft of each spindle can be set individually, so that a variety of yarns can be run on the same frame; and (4) it is claimed that a softer yarn is produced.

H. J. Burnham

Text. Research J. June 1947

Nylon Travelers

Nylon twister travelers. Anon. *Textile Industries* **111**, 90 (Apr. 1947).

A brief report on limited experience with nylon twister travelers for vertical rings. Increased spindle speeds, longer traveler life, and elimination of greasing rings are said to be some of the advantages obtained. H. J. Burnham

Text. Research J. June 1947

O.T.S. REPORTS *

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German Sewing-Thread Industry

A general investigation of the sewing-thread industry in Germany, including machinery, processes, and production methods. E. B. Adams and H. H. Bull. (BIOS Final Rept. 947, Item 21, 31.) PB L 60393, Nov. 1946; 29 pp.; microfilm, $1.00—photostat,$2.00 (through *Bib. Sci. and Ind. Reports* **5**, 130 (Apr. 11, 1947)).

This is a general investigation of the sewing-thread industry in Germany, including machinery, processes, and production methods. Unavailability of cotton and a general lack of fundamental raw materials is preventing any real progress in re-establishing the industry and a return to anything approaching pre-war output in quality and quantity will take many years, according to the report. Brief notes on methods and equipment at 7 establishments including a textile machinery manufacturer, a model spinning and weaving mill, a technical institute and 4 thread-processing plants are given as follows: Deutsche Spinnereimaschinenbau A. G., Ingolstadt; Zwirnerei & Nähfaden-Fabrik, Goggingen nr. Augsburg; Julius Schürer A. G., Augsburg; Lehrspinnerei Denkendorf, Esslingen; Zwirnerei Ackermann A. G., Heilbron; J. J. Anner, Zwirnerei & Nähfaden-Fabrik, Reutlingen; and Deutsches Forschungsinstitut für Textilindustrie, Reutlingen.

Text. Research J. June 1947

German Proofing Industry

Survey of the German heavy textile proofing industry. D. J. M.

* Copies of these reports may be obtained from the Office of Technical Services, Department of Commerce, Washington 25, D. C. Orders should be accompanied by check or money order payable to the Treasurer of the United States.

Smith and others. (BIOS Final Rept. 698, Item 22, 31.) PB A 45250, Aug. 1946; 21 pp.; microfilm, $1.00—photostat, $2.00 (through *Bib. Sci. and Ind. Reports* **5**, 130 (Apr. 11, 1947)).

The survey of the industry considered the preparatory processes, rotproofing, waterproofing, fireproofing, preparation of tents and tarpaulins, and technical control and research. No firm was found which engaged solely in proofing. Most of the firms did weaving, dyeing, proofing, and "making up" (fabrication of items such as tents and tarpaulins). In general the yarns employed were spun from flax, true hemp, cottonized bast fibers, and rayon staple and continuous fibers. There was no evidence of research into fabric constructions suitable for water-holding or waterproofing purposes. It was evident that the industry relied largely upon proprietary products marketed by I. G. Farbenindustrie A.G. for all types of proofing. The more important of the firms visited are dealt with in greater detail in the appendices, including L. Strohmeyer, Konstanz; Val Mehler, Fulda; K. A. Henschel (incorporating Frölich & Wolff), Hess-Lichtenau; H. Windel, Bielefeld, Hansa Schwerweberei; and I. G., Höchst. Appendix G gives the composition of some I. G. proofing products.

Text. Research J. June 1947

MISCELLANEOUS

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Air Contamination

Air contamination in cotton textile processing. Leslie Silverman. *Textile Industries* **111**, 84–6, 152 (Apr. 1947).

A report on a study made into dust and air-borne lint in cotton mills with special attention paid to conditions which might be termed a hazard to health. Highest concentrations of air contamination occur during opening, picking, and carding, but it is said that the health conditions of the textile industry compare favorably with other large industries. The return air condenser in combination with cloth bag filters is very effective in reducing air-borne lint and dust.

H. J. Burnham

Text. Research J. June 1947

Health Hazards in Cotton Mills

Air contamination in cotton textile processes. Leslie Silverman. *National Safety News* **55**, 24–6, 102–4 (Apr. 1947).

A research project is now underway to investigate and improve air conditions in cotton manufacturing. The cotton industry compares favorably with other large industries in lack of health hazards. There are two minor occupational diseases in cotton mills which can be attributed to air contaminants: a cotton-mill fever or Monday fever, which is a temporary fever probably caused by a bacterium carried on or in cotton dust; and a lung condition called byssinosis (cotton workers pneumoconiosis) which has been observed frequently in England and recently has been reported in this country. The first can be eliminated by effective dust control and the second by effective dust and air-borne lint control, but no satisfactory medical or prophylactic treatment has yet been devised for either. Sources of air contamination and methods of obtaining data on amounts of dust and air-borne lint are given. Possible control measures include application of oil to stock or moisture-conditioning it, and enclosure of contamination-making operations combined with local exhaust ventilation. The feasibility of more effective cleaning at gins is discussed. References are given. R. B. Evans

Text. Research J. June 1947

Flammable Clothing

Accidents from highly flammable clothing. Majorie W. Sandholzer. J. Home Econ. **39**, 133–4 (Mar. 1947).

Flammability of various textile fibers and fabrics, and efforts to develop improved flameproofing methods, are discussed. Of 47 accidents where the unusually flammable nature of certain fabrics appeared responsible, 40 involved napped rayons or cottons with particularly long fibers; 37 of these were cowboy-suit accidents.

Text. Research J. June 1947 R. B. Evans

Cotton Fabrics for Bags

The market for cotton textiles in bags. Robert B. Evans, R. J. Cheatham, and Barkley Meadows. New Orleans, Southern Regional Research Lab., Mar. 1947. 14 pp.

Consumption of cotton fabrics in bags climbed from 816,000,000 yds. in 1939 to 1,283,000,000 yds. in 1943, then declined to about 700,000,000 yds. in 1946. It is expected that this market will be adversely affected by trends toward using paper bags and bulk handling for some commodities but that it will be favorably affected by a well-sustained over-all demand for packaging materials and by a growing demand for cotton feed bags.

Text. Research J. June 1947 R. B. Evans

Cotton-Growing in Southern Europe

Unirrigated cotton in Southern Russia and the Danubian Countries. Naum Jasny. Foreign Agri. **11**, 2–14 (Jan. 1947).

Efforts have been made to grow unirrigated cotton farther north than its usually considered limits in the above countries, employing early, short-staple varieties and appropriate growing techniques. It is concluded that such production is generally uneconomic but might be advantageous in certain areas if better varieties are developed and if there is no alternative opportunity for labor. Climatic conditions, varieties, yields, growing techniques, labor, and economic conditions are discussed. R. B. Evans

Text. Research J. June 1947

Cotton Statistics

Cotton production and distribution, season of 1945–46. Bulletin 183, Bureau of the Census, Depart-

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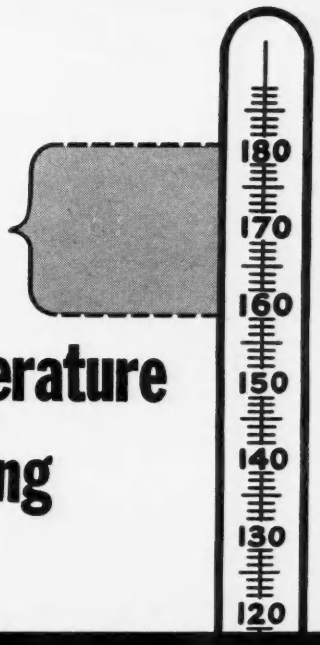

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ment of Commerce. Washington, U. S. Govt. Printing Office, 1946. 75 pp. Price, 20 cents.

This annual compilation gives basic data on acreage and ginnings, bale weights, consumption and stocks of cotton, imports and exports of cotton, and on cottonseed and cottonseed products in the United States. R. B. Evans

Text. Research J. June 1947

Diastatic Preparations

Diastatic preparations in the textile industry. G. Cattaneo. *Tinctoria* **43**, 132–3, 160–2 (1946) (through *Chem. Abstr.* **41**, 2248*b* (Apr. 10, 1947)).

A review of the diastatic preparations from malt, pancreas, bacteria, and fungi, as well as of commercial diastatic preparations and their use in the textile industry.

Text. Research J. June 1947

Felt Manufacture and Uses

Everybody uses felt. Niran Bates Pope. *Chemurgic Digest* **5**, 389, 391–6, 409–19 (Dec. 15 and 31, 1946).

Definition, theoretical development, history, application, manufacture, and classification of wool felts are discussed comprehensively. References are given. R. B. Evans

Text. Research J. June 1947

Natural Gum for Textiles

The gum of *Entandrophragma grandifolia*. M. Bachstez and G. Cavallini. *Farmaco sci. e tec.* **1**, 256 (1946) (through *Chem. Abstr.* **41**, 1862*d* (Mar. 20, 1947)).

The gum resembles agar-agar. On hydrolysis it yields galactose. HNO_3 oxidation of this galactose gives a quantity of mucic acid that indicates a galactan content of the gum equivalent to 23.2% galactose. The gum may find application in the textile industry.

Text. Research J. June 1947

Palmetto Fiber

Saw palmetto, a new raw material. George Anderson. *Mfrs.' Record* **115**, 40–1, 74, 78 (Dec. 1946).

A company has been organized to exploit saw or scrub palmetto, which covers an estimated 3,500,000 acres in Florida. Production of fiber for upholstery, brushes, rope, and paper pulp is envisioned.

Text. Research J. June 1947 R. B. Evans

Minor Fiber Industries

Minor fiber industries. Brittain B. Robinson. *Economic Botany* **1**, 47–56 (Jan.–Mar. 1947).

Collection, processing, and utilization of Spanish moss, palmetto, Spartina grass, and teasel in the United States are described. Spanish moss grows along the Atlantic and Gulf coasts, from Virginia southward, and, after curing and ginning, is used largely as a filler for upholstery. Palmetto, grown chiefly in Florida and in other Southern States, is used in brushes because it remains stiff in hot water and caustics. Spartina grass from Florida, Louisiana, and New Mexico is used primarily as a substitute for broom corn in making brooms. Needles of burs from teasel plants, cultivated in New York State and Oregon as well as in Europe, are used to raise the nap or pile of fabrics. R. B. Evans

Text. Research J. June 1947

Water-Soluble Phenolics

Liquid phenolic resins. Anon. *Brit. Plastics* **18**, 543–7 (Dec. 1946).

This survey covers the chemistry, properties, and applications of "water-soluble phenolic resins." Particular attention is paid to applications in the plywood industry, in anti-corrosion coats, and in cast articles. R. W. Eyler

Text. Research J. June 1947

Plastics Review

Recent advances in plastics. N. J. L. Megson. *Brit. Plastics* **18**, 478–83 (Nov. 1946).

The author summarizes wartime developments on several types of plastics. Those discussed at some length include phenolic and polyvinyl types, acetylene derivatives, polyurethanes, silicones, polytetrafluoroethylene, and ion-exchange resins. Other types are mentioned only briefly. German developments are given considerable attention. 17 references.

Text. Research J. June 1947 R. W. Eyler

Corrosion Resistant Plastics

Corrosion-resistant plastics. Anon. *Brit. Plastics* **18**, 389–95 (Sept. 1946).

A comprehensive review on Keebush and Keeware, both forms of phenolic resins used for chemical plant construction. Composition of these resins and fabrication of finished articles without high pressure molds and heat presses are described. Tables are given comparing the effect of various typical liquors used in textile industries on Keebush and stainless steel. Physical properties of the resins are described. Photographs showing plant applications are included.

Text. Research J. June 1947 R. W. Eyler

Polyethylene

Polythene. F. A. Freeth. *Brit. Plastics* **18**, 444–7 (Oct. 1946).

A review describing the solid polymers of ethylene produced by subjecting the gas to high pressures. Physical and chemical properties of these polymers as well as their history, preparation, and the fabrication of polythene articles are discussed. R. W. Eyler

Text. Research J. June 1947

Gas Heating Appliances

Gas heating applicances. Anon. *Brit. Plastics* **18**, 406–7 (Sept. 1946).

Application of radiant heating by gas-fired heating panels to the curing of materials coated with polyvinyl chloride is discussed. Finished materials in a variety of colors and thicknesses are reported. Continuous-process tests and details of construction of the heating panel are given.

Text. Research J. June 1947 R. W. Eyler